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Proceedings of a Workshop on a Proposed Experimental Lakes Area Whole-Lake Organic Contaminant Experiment at the Canada Centre for Inland Waters, Burlington, Ontario, January 7th and 8th, 1991

D.C.G. Muir

Central and Arctic Region
Department of Fisheries and Oceans
Winnipeg, Manitoba R3T 2N6

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PROCEEDINGS OF A WORKSHOP ON A PROPOSED EXPERIMENTAL LAKES AREA WHOLE-LAKE ORGANIC CONTAMINANT EXPERIMENT AT THE CANADA CENTRE FOR INLAND WATERS, BURLINGTON, ONTARIO, JANUARY 7TH AND 8TH, 1991

Edited by

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SUMMARY

A workshop was held January 7th and 8th, 1991, at the Canada Centre for Inland Waters in Burlington, Ontario, to review the need for and the feasibility of a whole-lake organic contaminant addition experiment proposed for the Experimental Lakes Area. The workshop was attended by 45 scientists and administrators from Fisheries and Oceans (DFO), Canadian Wildlife Service, National Water Research Institute, Ontario Ministry of Environment and Ministry of Natural Resources, Federal Environmental Assessment and Review Office, as well as scientists from universities in Canada and the United States.

General objectives of the workshop were to (1) Confirm the need for such an experiment, (2) Review organic contaminants of concern in the Great Lakes and identify the chemical of choice, (3) Identify the studies required, their scope, sampling protocols and likely costs, (4) Define the potential participation of non-DFO Winnipeg scientists, and (5) Identify environmental impact assessment (EIA) requirements and social issues. Individual working groups on Environmental Chemistry, Biochemical and Physiological Effects, Population and Ecosystem Effects, and Regulatory and Social Issues addressed one or more of the objectives.

The working groups concluded that there was indeed a need for such an experiment, that it was feasible, and that PCBs should be the chemical studied with the objective of thoroughly assessing their impact on natural populations on a whole-lake scale. A whole-lake experimental format was viewed as a logical extension of ongoing ecotoxicological studies pertaining to the Great Lakes that would provide a means to develop and validate methodology and diagnostic indicators, to assess the "health" of fish populations, their food webs and their habitats. The experiment would have the aim of defining environmental quality criteria for PCBs in sediment, water, and fish, required for ecosystem protection.

The proposed experiment would test the hypothesis that the addition of PCBs to levels currently found in Great Lakes sediments would produce reproductive failure in biota. It would be a multigeneration study in a small Canadian shield lake containing naturally reproducing populations of lake trout and lower trophic level organisms. It could confirm or refute many inferred cause and effect relationships which cannot be proven rigorously within the Great Lakes themselves. Other benefits would be improved knowledge of food chain dynamics and chemical limnology of organic contaminants. The experiment will also contribute to design and assessment of possible remediation strategies for sediment-associated pollutants and would develop insights to support the concept of zero-discharge.

It was recommended that an environmental impact assessment document describing the experiment be prepared following discussion with provincial and federal departments, and with environmental groups, and submitted for approval by the appropriate authorities.

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ABSTRACT

Muir, D.C.G. (ed.) 1992. Proceedings of a workshop on a proposed Experimental Lakes Area whole-lake organic contaminant experiment at the Canada Centre for Inland Waters, Burlington, Ontario, January 7th and 8th, 1991. Can. Manuscr. Rep. fish. Aquat. Sci. 2140: iv + 49 p.

A workshop was held January 7th and 8th, 1991, at the Canada Centre for Inland Waters in Burlington, Ontario, to review the need for and the feasibility of a whole-lake organic contaminant addition experiment proposed for the Experimental Lakes Area. General objectives of the workshop were to (1) confirm the need for such an experiment, (2) review organic contaminants of concern in the Great Lakes and identify the chemical of choice, (3) identify the studies required, their scope, sampling protocols and likely costs, (4) define potential participation of scientists from outside of the Department of Fisheries and Oceans, and (5) identify environmental impact assessment requirements and social issues. The conclusions of the workshop were that there was a need for such an experiment, that it was feasible, and that PCBs should be the chemical studied with the objective of thoroughly assessing their impacts on natural populations on a whole-lake scale. Workshop participants also noted that the experiment would provide a means to develop and validate methodology and diagnostic indicators for fish and ecosystem "health" and would help to define environmental quality criteria for PCBs in sediment, water and fish. It was recommended that an environmental impact assessment document be prepared describing the experiment following discussion with provincial and federal departments and with environmental groups.

Key words: whole lake experiment; PCB; conferences; Experimental Lakes Area.

RÉSUMÉ

Muir, D.C.G. (ed.) 1992. Proceedings of a workshop on a proposed Experimental Lakes Area whole-lake organic contaminant experiment at the Canada Centre for Inland Waters, Burlington, Ontario, January 7th and 8th, 1991. Can. Manuscr. Rep. fish. Aquat. Sci. 2140: iv + 49 p.

Le Centre canadien des eaux intérieures de Burlington, Ontario, a tenu un atelier les 7 et 8 janvier 1991 afin d'examiner la nécessité ainsi que la faisabilité de procéder à une expérience qui constitue essentiellement en l'addition de contaminants organiques à l'échelle d'un des lacs de la Région des Lacs Expérimentaux. Cet atelier avait les objectifs généraux suivants : 1. confirmer la nécessité de procéder à une expérience de cet ordre; 2. examiner la liste des contaminants organiques préoccupants des Grands Lacs et déterminer lequel pourrait être utilisé pour l'expérience; 3. déterminer les études requises, la portée, les protocoles d'échantillonnage et les coûts probables; 4. déterminer le niveau de participation éventuelle de chercheurs qui n'appartiennent pas au ministère des Pêches et des Océans; et 5. déterminer les exigences en matiére d'évaluation des répercussions environnementales, ainsi que la portée sociale. Les participants sont parvenus à la conclusion qu'il serait utile de procéder à une expérience de cet ordre, qu'elle était faisable et que les BPC devaient constituer le groupe de composés chimiques étudiés en vue d'évaluer en profondeur les répercussions de ces substances sur les populations naturelles et à l'échelle d'un lac. Les participants ont aussi signalé que l'expérience serait une façon de développer et de valider une méthodologie et des indicateurs servant au diagnostic de la santé de populations de poissons et de l'état d'écosystèmes, qu'elle pourrait concourrir à dèfinir des critères de qualité du milieu relatifs aux BPC dans les sédiments, l'eau et le poisson. Il a été recommandé qu'à la suite d'échanges avec des ministères fédéraux et provinciaux ainsi que des groupes de protection de l'environnement, un document d'évaluation des répercussions environnementales qui décrirait l'expérience.

Mots clés : expérience à l'échelle d'un lac; BPC; conférences; Région de Lacs Expérimentaux.

INTRODUCTION

A workshop was held January 7th and 8th 1991, at the Canada Centre for Inland Waters in Burlington, to review the need for and the feasibility of a whole-lake experiment on organic contaminants proposed for the Experimental Lakes Area. The workshop was attended by 50 scientists and administrators from the Department of Fisheries and Oceans (DFO), the Canadian Wildlife Service, the National Water Research Institute, Ontario Ministry of Environment and Ministry of Natural Resources, the Federal Environmental Review and Assessment Office, as well as scientists from universities in Canada and the United States.

General objectives of the workshop were to (1) Confirm the need for such an experiment, (2) Review organic contaminants of concern in the Great Lakes and identify the chemical of choice, (3) Identify the studies required, their scope, sampling protocols and likely costs, (4) Define the potential participation of non-DFO Winnipeg scientists, and (5) Identify environmental impact assessment (EIA) requirements and social issues.

The detailed workshop program is outlined in Appendix 1. The workshop began Monday morning with opening remarks from Dr. John Cooley (Director, Physical and Chemical Sciences, DFO, Burlington) and from workshop chairman Dr. Jack Klaverkamp. This was followed by a plenary session consisting of three presentations giving background on previous whole-lake studies at ELA (by Dr. Bob Hecky, Dr. Diane Malley and Dr. Dave Schindler), and an overview of environmental chemistry studies on polychlorinated biphenyls (PCBs) in the Great Lakes by Dr. Steve Eisenreich. In the afternoon Dr. Chris Metcalfe presented a review of ecotoxicological effects of PCBs and polyaromatic hydrocarbons (PAH). Condensed versions of these presentations were prepared from notes and handouts of the speakers and are presented below (pages 3-12). Dr. Derek Muir then presented a preliminary "strawman" design of the whole-lake experiment. This presentation included progress to date and tentative plans for the period April 1, 1991 to March 31, 1992 which are summarized in Appendix 2. This was followed by discussions of individual working groups on environmental chemistry, biochemical and physiological effects, population and ecosystem effects and regulatory and social issues. These groups were asked to address a series of questions on specific aspects of the experiment. A full list of the questions for each working group is given in Appendix 3. Tuesday morning was devoted to preliminary reports from the working groups and especially to a lively debate on what chemical should be selected for the experiment. Detailed notes, believed to accurately reflect each speaker's remarks during the Tuesday morning discussions, are presented on pages 20 to 25. After further discussions, the working groups presented their final reports on Tuesday afternoon. The final reports and recommendations of the working groups are presented on pages 26 to 40.

Summary of Working Group Recommendations

The chemical/mode/timing:

- PCBs are the best choice for a study to assess the hypothesis concerning the reproductive failure of a lake trout population
- fall, hypolimnetic, addition once per year as an acetone solution
- use of bioassay to give single "TCDD equivalents" result will address concerns about a "mixture" of congeners
- incremental addition of chemical to look for effects thresholds

Measurements:

- do a chemical mass balance annually.
- food chain samples should emphasize benthos and fathead minnows as well as fish-eating ducks etc.
- exhaustive characterization of reproduction by **all** species of fish in the lake, including MFO, thyroid, gonad, etc.
- obtain and archive samples for later chemical and effects measurements

Regulatory and social issues:

- experiment can be rendered socially and politically feasible with appropriate planning, management and communication. Need formal public liaison mechanism
- develop a communications "package" with details on the experimental objectives, benefits (local and broad), participation, emphasizing carefully controlled experiment and remediation/recovery/restoration.
- form a "committee of scientific participants" to develop, adjust and implement aspects of study design.
- addition of PCBs will probably require an Order-in-Council under Section 36 of the Fisheries Act.
- project will be screened under EARP.

PRESENTATIONS

Opening Remarks

J.M. Cooley, Director, Physical and Chemical Sciences, Department of Fisheries and Oceans, Central and Arctic Region, Burlington.

The proposed experiments at ELA date back to the 1960s when work on the 1972 Great Lakes Water Quality Agreement was based largely on whole-lake work on eutrophication at ELA. With the signing of the new Great Lakes Water Quality Agreement in 1987 it was realized that it was time once again to conduct some experiments at ELA because of the unique scientific possibilities there. These experiments have the potential to evaluate existing and proposed regulatory actions on both water and sediments, and they can contribute to remedial actions.

In view of the cost of whole-lake experiments, it is most important that they be done correctly. They represent long-term commitments of both staff and dollars, and they can normally be done only once. It is the purpose of this meeting to derive the best experimental design we can.

Introductory Remarks

Jack Klaverkamp, Department of Fisheries and Oceans, Winnipeg.

About one-quarter of the people at this workshop representing a wide range of scientific expertise, have worked at ELA. The first three speakers will describe the setting at ELA and some of the past and current experiments there, in the hope that this will help the non-ELA participants to contribute to discussions later this afternoon and tomorrow. The remaining speakers are expert on either the behaviour or the effects of organic contaminants in the Great Lakes.

This year we received funding to begin planning a whole-lake experiment with an organic contaminant, and we have reached a stage in planning where we need critical input from a wide range of disciplines, and that is why we have invited you here. Some of you are expert in regulatory matters and societal problems to which we want the experiment to serve, and we particularly invite your thoughts.

Derek Muir will be laying out a "straw man" proposal and we want you to take it as just that. We have tried to develop what we think may be a workable proposal, but nothing is written in stone. We need your help with the "nuts and bolts" of how to do the experiment if you think the idea and approach is reasonable. Alternately if you have better ideas for the overall approach then we invite your thoughts.

Historical and Current Experiments at ELA

Bob Hecky, Department of Fisheries and Oceans, Winnipeg.

By agreement with the Government of Ontario there are 46 lakes at ELA available for experimental manipulation. Most current experiments derive from our interest in the long-range transport of atmospheric pollutants (LRTAP). The first suggestion that an organic contaminant be tested on a whole-lake scale at ELA was made by Eville Gorham in 1987 at a workshop in Burlington when the DFO-LRTAP program was being expanded to include organic contaminants in addition to acid-forming materials.

One aspect of our agreement with Ontario is that we must restore ELA lakes as completely as possible to their original condition at the completion of our experiments, and we have to give some consideration to how that might be done in the experiment which will be proposed. Remediation must be a design aspect from the beginning and it is of course a major issue with a lot of the in situ persistent organochlorines which are no longer manufactured.

Past Experiments at ELA

Early experiments at ELA were directed at the problem of eutrophication of the Great Lakes. A double-basin lake was curtained off in the middle; one basin was then fertilized with the other basin serving as an untreated control. The results were visually dramatic; a photograph of the two basins showed one basin clear and blue and the other distinctly green. Such clear-cut results are persuasive when dealing with government regulatory people who need clear demonstrations that contamination really matters.

One objection to the use of small experimental systems at ELA to help with Great Lakes problems is the problem of extrapolating from small shield lakes to very large Great Lakes. We are trying to evaluate this through a study of a series of lakes varying logarithmically in size from Lake 375 up to large lakes (Nipigon, Superior).

Another problem with whole-lake experiments is their apparent cost. Compared to a laboratory experiment they are indeed costly, however, compared to oceanographic work in which ship time is included, they are quite reasonable.

The ELA approach to experiments typically is more than a whole-lake manipulation. It is conducted at several scales, including laboratory experiments, limnocorral experiments, and whole ecosystem experiments.

Lake 223 Acidification

Lake 223 was acidified experimentally over several years by addition of sulfuric acid to the epilimnion. Ecological effects were observed from algae to fish. For example, the species composition of algae changed strikingly although the total algal biomass changed very little. The changes have not been fully reversible although the experiment is now in a recovery phase with pH increasing. Similarly the benthic community composition and productivity have not recovered yet despite pH recovery. The acid stress resulted in a much simpler food chain with prey species of fish being lost and resultant reduction in lake trout condition. Lake trout condition and reproduction did recover rapidly with the relief of acid stress, but other food chain components may take much longer. Again pictures of the emaciated "acid-stressed" lake trout and healthy "recovered" trout have been persuasive in convincing government agencies in both Canada and U.S.A. that action must be taken to limit acid emissions.

Why do whole-lake experiments? If the aim is to understand whole-system functions, then you have to work with the whole system. It is the smallest scale at which the naturally reproducing populations of the largest organisms can be studied. The scale is large but if you want to be convincing in the real world then you need data from the real world. This has obvious advantages and disadvantages. The available scale runs from:

Laboratory culture	-----	extensive control
Natural assemblages in lab		
Enclosures		
Natural system	-----	Limited control and replication.

At the natural system level you cannot control very much beyond the addition of the stressor, and so you must be careful to get the design and implementation right the first time.

Current whole-system experiments at ELA are:

Lake 227 - eutrophication
Lake 221 - biomanipulation (pike introduced into a perch lake)
Lake 302 south - acute acidification
Lake 223 - acidification, now in recovery stage
Lake 302 north - role of phosphorus in modifying acidification with nitric acid
Lake 382 - cadmium
Wetland flooding and its effects on mercury cycling
Wetland and upland acidification.

These ongoing experiments provide a profile of ecosystem stresses against which the type and significance of any new stress experiment can be assessed for impact on aquatic ecosystems.

Some questions and choices we have to consider include the issue of ecosystem health vs. human health as the appropriate experimental end-point. This choice is exemplified by the decision to use cadmium instead of mercury in the Lake 382 experiments. Mercury is already regulated in fish to protect the health of fish consumers, and the level is sufficiently low to also protect the health of the fish. Another choice is one of emphasis on LRTAP vs. that of Great Lakes problems. When we started thinking of whole-lake experiments with organic contaminants our interest was LRTAP, but the support foe these experiments is coming from the Great Lakes funding, not LRTAP. Consequently some changes are needed; remediation may play a larger role in our design than it would under the LRTAP mandate. The purpose of the experiment can include "pathways" vs. "effects" vs. "remediation". We might be able to use multiple stressors and do a stronger pathways experiment, but then the allocation of effects will become more awkward. We will need to decide the time frame of the experiments, the treatment protocols, the recovery strategies, etc. Several questions arise. The issue of PCBs is already decided at the regulatory level. PCBs are "bad" and regulatory action was taken long ago to stop their manufacture; however, despite cessation of manufacture there are substantial quantities of PCBs cycling in the environment. The crucial question to be answered is whether this <u>in situ</u> material is a substantial depressor of fish health, fish growth and human health. Other design and utility questions are; is a single stressor possible or desirable because PCBs were produced and released as complex mixtures? Does a single, small lake (N=1) represent an adequate design? Is it relevant to the Great Lakes in view of the lack of replication and of different spatial scales and food chain structures? Will the public object to the experiment, especially in view of the action to stop PCBs some years ago? This workshop will hopefully provide strong, clear answers to these questions.

Whole Lake Experimental Addition of Cadmium at ELA

Diane Malley, Department of Fisheries and Oceans, Winnipeg.

Introduction

Research at the Experimental Lakes Area on pollutants subject to long-range atmospheric transport (LRTAP) began by focusing on acids. But because large contributions of acidic precursors in Canada originate from nonferrous metal smeltering, volatile metals such as cadmium (Cd) were also soon considered to be LRTAP pollutants. Cadmium was chosen in the late 1970's as the metal for study principally because it is highly toxic to aquatic life and is found in some freshwaters near to or exceeding toxic concentrations. Regulations set to protect human health in respect to Cd (e.g. 5-10 μg/L for drinking water) are too high to protect aquatic life. There was concern that the guidelines or objectives set for the purpose of protecting aquatic life from Cd were too high. The Canadian Water Quality Guideline for Cd is 0.2 μg/L for aquatic systems with hardness less than 60 mg/L as calcium carbonate.

Whole lake experimental approach

As for other contaminants, Cd was studied at the Experimental Lakes Area (ELA), northwestern Ontario by experimentally adding it to a whole lake. The main objective of this experiment was to describe the geochemical and biological pathways of low levels of Cd from between water, sediments and organisms and to determine the progression of stress caused by Cd from the molecular to the ecological levels of organization. The experiment permits us to test the adequacy of the Canadian Water Quality Guideline of 0.2 μg/L in protecting the biota of soft waters. It also permits us to observe the importance of the sediments as a sink for Cd; to identify some responses which may serve as early-warning indicators of impending ecological damage and to assess the predictive value of results from small-scale, laboratory, microcosm or mesocosm experiments against the response of individuals and populations exposed in the lake. At least 30 researchers from three organizations are collaborating in this experiment.

Experimental methods

Lake 382, typical of ELA lakes in size (37.7 ha) and bathymetry (13.1 m in maximum depth), was selected for its characteristic Precambrian Shield water chemistry and relatively large population of lake trout. The lake contains 2.2 mg/L dissolved calcium and has a hardness of 7.0 mg/L as calcium carbonate.

Starting in June 1987, the epilimnion of Lake 382 was annually loaded with Cd and ^{109}Cd (0.00455 μg Cd/cpm) during the ice-free season. Target concentrations were 0.10, 0.10, 0.12 and 0.16 μg/L Cd in 1987 to 1990, respectively. The radioactive Cd was added to facilitate tracing the fate and accumulation of Cd. Most of the concentrations of Cd reported below are calculated from the [^{109}Cd]. In the first four years, 975, 643, 778 and 1435 g of Cd were added. In March 1989, 23 sediment cores were taken along three transects radiating from the deepest point in the lake. To date, 10 cores have been analysed for [^{109}Cd] and for [^{210}Pb]. The ^{210}Pb dating is used to estimate depth of the mixed layer in a core.

The fate (accumulation) of Cd has been measured in organisms from all of the trophic levels in Lake 382. Effects of Cd were and are being examined in respect to algal productivity, phytoplankton diversity and community structure, zooplankton community structure, mussel physiology (blood ionic composition, production of metallothionein) and fish structure and

function. Lake 382 contains an estimated 550 lake trout (about twice as many as typical of ELA lakes of its size) along with about 2000 white suckers. These populations are large enough to sustain periodic sampling. Parameters examined in fish include:

1. Tissue uptake and distribution of Cd (Primary Response):

   Levels of Cd in the vital organs are determined; these can then be related to physiological and pathological effects. The relationships derived from comparison between Cd burden and effects can then be used to predict consequences of similar Cd levels in other systems regardless of differences in water quality.

2. Biochemical and histological effects (Secondary Response):

   a. Carbohydrate metabolism (energy).
   b. Ionoregulation (maintenance of homeostasis).
   c. Metallothionein, acid-soluble thiols and ascorbate.

3. Whole-animal effects (Tertiary Response):

   a. Growth indices.
   b. Reproductive indices.
   c. Behavioral responses.

4. Population and community effects (Quaternary Response):

   a. Population parameters: growth rates, survival,recruitment and abundance.
   b. Community parameters: population ratios, etc.

Synopsis of results

Over 4 years, a total of 3.8 kg of Cd has been added to Lake 382. This has raised the concentration of Cd in the epilimnion from 0.0016 μg/L to 0.050-0.180 μg/L. Most of the Cd added (at least 73%, but probably more than 90%) remains in the sediments. Although the lake is substantially contaminated by Cd, the water has not exceeded the Canadian Water Quality Guideline of 0.2 μg/L.

There is no evidence of effects on primary production or nutrient cycles but the phytoplankton community may be showing decreased diversity. Cadmium has accumulated in phytoplankton, zooplankton, benthic insects, crayfish, mussels, macrophytes and fish with organisms containing up to 30 times background levels. Some zooplankters may be avoiding the high-Cd water. Based on in situ flow-through experiments on zooplankton, adverse effects on some cladocerans are expected at 0.2 μg/L. Mussels have elevated metallothionein levels; they have not yet reached equilibrium with the added Cd.

Cd has accumulated in Lake 382 fish and the findings suggest that equilibrium between Cd and large fish (white sucker and lake trout) has not been obtained. There is little evidence of increased metallothionein levels in tissues. Presently, the low environmental Cd has not yet induced clear evidence of detrimental effects on fish as judged by biochemical, histopathological and population measurements. Nevertheless, kidneys of lake trout and white sucker contain Cd (4 μg/g wet weight) at about 50% of the concentrations which produce histopathological lesions in rats. Our long-term laboratory studies indicate that biochemical and histological effects occur in lake trout when Cd concentrations reach approximately 8-10 μg/g in vital organs (liver and kidney). In the laboratory, biochemical responses were evident in more sensitive rainbow trout when tissue Cd levels were 2-4 μg/g.

Reduced gonadosomatic index, egg size and number of vitellogenic oocytes observed in the lake trout in Lake 382 in 1988 were not seen in 1989. If the reproductive effect in 1988 was an initial response to Cd, then compensation or acclimation has occurred. Lowered energy reserves found in trout during the latter part of 1987 and at the beginning of 1988 may have caused the lower fecundity. Lake trout in Lake 382 appear to rely more heavily on invertebrate prey than do trout in reference lakes. This coupled with their low growth rate would suggest that the trout may be more susceptible to declines in zooplankton than fish in other lakes. Depressed growth rates in juvenile year classes of white sucker may represent an early effect of Cd but further studies are required for verification.

In the laboratory, lake whitefish, also an ELA species, could detect and avoid water containing Cd as low as 200 ng/L.

We conclude that water quality guidelines alone are not sufficient to protect soft water systems from the effects of Cd because they do not prevent long-term accumulation of Cd in the sediments and biota. Sediment quality guidelines or restrictions on loading are required, as well, to protect freshwaters from persistent metals.

Contributors to the Cadmium experiment:

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Applications of ELA Studies

Dave Schindler, Department of Zoology, University of Alberta.

(Introduced as the only ELA scientist ever to have shaved his legs)

Whole-lake experiments have great ability to convince regulators of the need for actions. It is often the unplanned surprises in whole-lake experiments that provide the most insight. Calibrations of experiments of different scales are essential if it is to be argued that results at one scale are relevant to another one. In the cases of eutrophication the scientists working on the problem already knew that there was a need to limit inputs of phosphorus, but it was the dramatic visual evidence from ELA that gave the bureaucrats what they needed.

A number of experiments have shown that biological responses in the whole ecosystem could either not have been predicted at all, or would not have been predicted until much higher concentrations were reached. For example, in the case of eutrophication, soap companies argued that carbon was limiting, not phosphorus. This argument was convincingly tested and disproved by adding phosphorus and nitrogen to Lake 227 which had very low dissolved carbon. The result was dramatic eutrophication in spite of the fact that no carbon was added. The atmosphere was the source of the carbon needed. This single whole-lake experiment was able to counter the best arguments by the soap companies.

When the acidification work was started at Lake 223 there was little interest in effects of acidification on food chains. The pictures of the starving lake trout have been convincing for several U.S. states in their setting of state acid emissions. Until very recently few people have been sensitive to the problem of biological impoverishment. Lake 223 lost about half of its species as a result of the drop in pH to 5. Whole biological pathways were abolished; nitrification was stopped by pH 5.5. Comparisons of the responses at ELA in Lakes 223 and 302S with those from Little Rock Lake in Wisconsin have shown conclusively that results from one place apply to the others, especially with regard to the chemical fate of the acid added.

It is more difficult to generalize from tube experiments due to difficulties in scaling the experiments to properly represent ecosystems. Some work on eutrophication required three summers of tube studies to get the design to work properly.

Concentrations, Fluxes, and Cycling of PCBs in the Great Lakes: Air, Water, Sediment.

Steve Eisenreich - Gray Freshwater Biological Institute, University of Minnesota.

PCBs associate with particles when there are enough particles to sorb them. In the Great Lakes there are too few particles and so much of the PCB in the lake is not sorbed. The important interactions are those at interfaces (air/water, water/particles, sediment/water). Laboratory experiment with sorption to particles show a simple relationship between the sorption coefficient and the octanol-water partition coefficient (Kow) of the particular PCB, but field data from the Great Lakes show almost no relationship of sorption to Kow. The deviation from this expected relationship can have two explanations; there may be a third phase, the colloid phase, which is not really dissolved but which fails to separate from the water in the techniques used to separate dissolved from particulate phases, or, alternatively, true equilibrium may not be reached. Experiments have shown that the "colloid phase" becomes the dominant one at dissolved organic carbon levels of 2 to 3 mg/L.

Bioaccumulation of PCB congeners is expected to increase regularly as the Kow of the congeners increases. Data from Skoglund and Swackhamer (1991) on bioaccumulation in algae show that this is generally true for the PCBs low in chlorine content, but that bioaccumulation of congeners high in chlorine is essentially independent of Kow at short equilibration times. This is interpreted as evidence that the lower-chlorinated congeners are at or near true equilibrium, but that higher-chlorinated congeners are not. There is also a seasonal component to the attainment of equilibrium. The algae accumulate predicted amounts of the different congeners in winter, but much less than predicted amounts in summer. The degree of chlorine substitution at the ortho positions affects the bioaccumulation factors.

In a whole-lake experiment we will need to know how much PCB is in each phase. PCBs are removed from the water column by sedimentation processes. The movement throughout the water column is much faster (by about 100 x) than the rate of accumulation in the sediments in Lake Superior. Algae are dominated by lower chlorinated PCBs more while the sediment PCBs are predominately the higher chlorinated congeners. PCBs leave the water column within days of deposition. The controlling actions are in the benthic area; the PCBs on the particles reach the bottom where the particles themselves are digested by the benthos and the PCBs then re-partition. The high-chlorine components are retained within the benthos and sediment more effectively than the low-chlorine components. The key to understanding PCB movements is the carbon cycle. There is a near perfect relationship between the flux of PCBs to sediments and the flux of organic carbon.

Volatilization is a relatively slow process for PCBs but it is very important in the Great Lakes because of their large surface area. It will not likely be significant in Lake 375. (Approximately 10 to 30 ug/m^2.day or perhaps 1 to 10 g lost from the lake per year.)

The sedimentation rate in lake 375 suggests that most PCB recycling will occur before the PCBs are buried. The depth of the mixed layer is important; in Lake Ontario the ^{210}Pb profiles show a mixed layer of about 3-5 cm in the eastern basin, and so changes in PCB inputs over the past 5-10 years should not be separable. However, ^{210}Pb is very strongly sorbed and does not move unless the particle itself moves; PCBs appear to have some tendency to move up and down, with low-chlorine PCBs moving by diffusion.

The Lake 375 experiment offers opportunities to develop sediment quality criteria for the Great Lakes. If we can establish that the equilibrium partitioning paradigm works, then we can easily calculate the sediment quality required to protect biota from accumulating a target quantity, and this will be required in remedial actions throughout the Great Lakes. Alternately, other sediment quality models may be devised from the failure of the equilibrium partitioning approach.

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Effects of Organic Contaminants in the Great Lakes

Chris Metcalfe, Trent University, Department of Biology and Environmental and Resource Studies Program, Peterborough.

This discussion will focus on polyaromatic hydrocarbons (PAHs) and coplanar PCBs. Several studies have illustrated fish health problems associated with these contaminants in the Great Lakes. Studies young chinook salmon and lake trout from Lake Michigan has shown poor survival at the swim-up stage; liver neoplasms and lip papillomas in bullheads from the Black river. Herring gulls showed reduced reproduction for several years in the early 1970's but have now recovered, however, young double-crested cormorants in the Green Bay area show an unusually high incidence of congenital abnormalities, notably crossed bills; in the late 60's mink on ranches feeding Great Lakes fish show impaired reproduction and natural populations in the Lake Ontario watershed now have similar PCB residues. *Clearly there are a number of overt effects*, especially at higher trophic levels.

PAHs show carcinogenicity, mutagenicity, embryotoxicity, behavioral toxicity, and reproductive toxicity. Johnson et al. (1988) have shown stronger statistical associations between induction of AHH enzymes, reduced plasma estradiol, and reduced ovary maturation in English sole, with sediment PAHs than with PCBs. The effect most frequently associated with PAHs is tumours. Recently Harshbarger and Clark (1990) have shown a map of tumour frequencies in the Great Lakes and they correspond well with maps of PAH distribution. High sediment PAHs in the Great Lakes are usually associated with point-source discharges from coking plants.

Tumours can be caused by parasites (at least in people), viruses (in fish) and chemicals - or possibly by combinations of these. Papillomas can arise from chemical/viral interactions, biliary tumours from chemicals in conjunction with bile duct disease, and hepatic tumours from chemical-chemical interactions. As an example of multiple chemical interaction, Myers et al. (1990) has shown in Puget Sound that English sole have a greater chance of developing tumours if they are exposed to both PAHs and PCBs.

In our lab at Trent University we have taken organic extracts of sediments from Hamilton Harbour and injected it into rainbow trout sac fry. Some months later the fish treated in this way develop hepatic tumours (Metcalfe et al. 1990). More recently we have fractionated the sediment extracts into six fractions of increasing polarity, and the tumour production is associated with not only the PAH fractions, but also with more polar fractions.

PCBs also have an array of toxic effects, including liver toxicity, thyroid toxicity, teratogenesis, embryotoxicity, neurotoxicity, immunotoxicity, and reproductive toxicity. The chlorine substitution pattern influences the toxicity greatly with "co-planar" congeners 77, 126, and 169 being the most toxic. Lack of ortho substitution allows the molecule to assume a planar configuration which confers upon it a dioxin-like toxicology. This similarity to dioxin toxicology has fostered the development of the "Toxic equivalent factor" approach, and work by Niimi and Oliver (1989) has given the following TEF values, in terms of the ability to induce AHH activity in rodents (AHH-TEFs).

Congener	TEF	Congener	TEF
2,3,7,8-TCDD	1	PCB-77[a]	0.0001
2,3,7,8-TCDF	0.08	PCB-105[b]	0.0008
PCB-126[a]	0.16	PCB-118[b]	0.000006
PCB-169[a]	0.0015		

[a] Non-ortho substituted, [b] Mono-ortho substituted

In spite of its low TEF value, PCB-118 is important because of its high environmental concentrations, and because of its embryotoxicity. When the TEF is combined with the environmental concentration, the co-planar PCBs generally outweigh the dioxin in their contribution to toxicity (on the assumption that relative toxicities expressed in this way can be added together).

At Trent, we have determined AHH-TEF's for rainbow trout exposed to TCDD and PCBs 77 and 126 (Janz and Metcalfe, 1991). Based upon concentrations of these compounds in Lake Ontario rainbow trout and the AHH-TEF's, the co-planar PCBs have the potential to be more toxic than TCDD (greater toxic equivalent quantities).

The relevance of AHH induction as an indicator of toxicity is often questioned since there are other more important biological responses. Data reported by Safe (1987) with mammals has shown an excellent correlation between the ED-50 for AHH induction and the EL-50 for thymic atrophy ($r=0.92$). Hence the association is very strong, although this does not establish a causal relationship between the two responses. There are also some unexpected interactions among these organochlorines. For example TCDD had a strong immunotoxic effect on mice, and this is almost abolished when PCBs (Aroclor 1254) are given along with the TCDD.

The proposed Lake 375 experiments can address several problems for the Great Lakes. In relation to the carcinogenicity of PAHs; chemical/disease interactions, chemical/chemical interactions, and population and community responses could be studied. In relation to co-planar PCB toxicity; toxic equivalent factors in aquatic organisms, combined chemical effects, chronic immunotoxicity, reproductive toxicology, population and community responses could be assessed.

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PRELIMINARY REPORTS OF WORKING GROUPS

Group 1: Environmental Chemistry - Tuesday Morning Report

Chairman: Steve Eisenreich, University of Minnesota
Rapporteur: Derek Muir, DFO Winnipeg
Members: Joel Baker, University of Maryland
Gregg Brunskill, DFO Winnipeg
John Carey, NWRI Burlington
Peter Landrum, NOAA Ann Arbor
Art Niimi, DFO Burlington
Ross Norstrom, CWS Hull
Mark Servos, DFO Burlington
Bill Strachan, NWRI Burlington
Ken Minns, DFO Burlington
Mike Whittle, DFO Burlington

There was a consensus that the chemical should be on a Great Lakes priority contaminant list. There was considerable discussion of whether to add a single compounds or a mixture. Dieldrin and 2,3,7,8-TCDF were mentioned as possible single compounds. Both are on Great Lakes priority contaminant lists. A single compound study was rejected by most participants. The strongest candidates that emerged in the discussion were PCBs and PAHs. Some of the pros and cons of both chemicals were discussed.

PAHs are an important class of contaminants in the Great Lakes. They induce mixed function enzyme activity in fish and, as reported by Chris Metcalfe on Monday AM, PAH metabolites in bile correlated with reproductive effects in Puget Sound flounder better than PCBs. On the other hand, PAH are only considered a problem in localized areas of the Great Lakes.

PCBs are associated with the reproductive failure of fisheries and of wildlife i.e birds and mammals. PCB mixtures are available which are similar to the mixture present in Great Lakes sediments. PCBs bioaccumulate and effects are likely to be seen in top predators. A strong argument for PCBs is that a lot is known about their environmental chemistry and toxicology. We know what concentrations to add and can predict what effects may be elicited based on the substantial laboratory and field data. On the other hand, because of the lack of knowledge on PAH effects and fate, an experiment with them might yield more new information.

If PCBs were to be used it was agreed that a single assay such as the rat heptatoma assay be used on extracts (of water, biota and sediment) to yield a single TCDD equivalents results. This would enable a single result for PCBs to be reported and comparison with the growing literature using this assay to be made. The results of the experiment could be used to validate the bioassay because only PCBs would be present as toxicants.

No consensus on the compound was formally reached Monday PM but the group moved onto discussing the method of addition of the chemical assuming that PCBs were to be added.

We discussed the idea of adding a coplanar PCB along with the mixture and rejected the idea. It was pointed out that an enriched mixture wouldn't be representative of the situation in the Great Lakes. It was felt that detection limits for most matrices would be adequate without enrichment - assuming the use of mass selective detection. It was suggested that other non toxic PCBs, not found in Aroclor mixtures, be added as internal standards.

After considerable discussion about various methods of addition i.e on particles, blocks of ice, etc., we reached a concensus that a PCB oil (pure Aroclor not transformer oil) should be added by injection of an acetone solution into the hypolimnion. We suggested a fall addition so that the chemical would be completely mixed at turnover. Other advantages of a fall addition were low volatilization, high concentrations of sedimenting particles, and more even distribution to the littoral and profundal zones. Probably 10's of grams could be added in 100's of mls of acetone by injection into water. Dilution factors of 10,000 or more could be achieved with suitable diffusers. Hundreds of grams of PCB could be added over a short period < 1 month, perhaps < 1 week. The use of the natural particle matrix would avoid selection of more or less readily bioavailable particles if we used bottom sediment or soil.

Group 2: Biochemical and Physiological Effects - Tuesday AM Report

Chairman: George Dixon, University of Waterloo
Rapporteur: Lyle Lockhart, DFO Winnipeg
Members: Jack Klaverkamp, DFO Winnipeg
Scott Brown, DFO Winnipeg
Peter Delorme, University of Manitoba
Jack Klaverkamp, DFO Winnipeg
Chris Metcalfe, Trent University
Kelly Munkittrick, DFO Burlington
Richard Peterson, University of Wisconsin
Ian Smith, OME Toronto
Gary Westlake, OME Toronto
Christine Bishop, CWS, Hull

Most of the time was used for debate of the question of which organic chemicals would be the most suitable for the long-term commitment of time and effort required to do a whole-lake experiment. It was agreed that there is wide interest in compounds which act toxicologically through the Ah receptor, or which at least act in parallel to action on this receptor. Consequently if we are interested in exploring the toxicological and ecological consequences of Ah receptor-associated changes, it does not matter very much what the chemical insult is, as long as it acts on this receptor. Four of the possible groups on the various priority lists have this type of action, namely the PAHs, the PCBs, TCDD/TCDF, and co-planar (non-ortho substituted) PCBs. Since we want to calibrate responses at biochemical and physiological levels against those at ecological levels, then it is important that we add enough to cause both types of responses.

What compound(s) should be added?

The group devised a series of criteria to help choose the compounds to be added. These were cost, availability of quantities needed, mechanism of toxic action, current regulatory status, analytical problems, and health considerations. Then a vote was taken with candidate groups being PAHs, TCDD/TCDF, co-planar PCBs and PCBs. The votes were scored after each member of the group had ranked the four groups, with highest priority being given a weight of 4, and lowest priority a weight of 1. The results were:

Group	Score
PAHs	36
PCBs	21
TCDD/TCDF	21
Co-planar PCBs	22

The main reasons given for the selection PAHs over PCBs were the current regulatory status of the groups, the state of existing knowledge, and the requirement for future cleanup.

Current regulatory status[1]

PCBs have not been manufactured in North America for some 13 years. There is nothing more that can be done to regulate them. Further work on PCBs cannot be justified on the basis of a need for information to support future controls. There are no specific regulations for co-planar PCBs, but they are included in regulations against PCBs.

TCDD/TCDFs are just now coming under regulation. The largest point sources are bleached kraft pulp mills and emissions from them are about to be regulated under new Canadian Environmental Protection Act (CEPA) and Fisheries Act regulations in Canada. Diffuse sources like municipal incinerators still exist and it is not known whether they will require regulation in the future. The co-planar PCBs may provide a model for the toxic mode of action of TCDD and TCDF, but information required for regulation of TCDD and TCDF will have to be generated on the compounds themselves not on the surrogates.

In contrast, there are not current regulations governing PAHs in discharges in Ontario, but the province is interested in developing them. The industries involved are steel, oil, thermoelectricity, and waste incineration. The whole lake experiment would be helpful in developing regulations if it used PAHs typical of several existing areas of concern.

Existing knowledge[1]

There is already a huge body of published information on the environmental fate and toxicology of PCBs. Several more years of work on them will be largely filling in academic gaps. Furthermore the levels the levels of PCBs in fish from the Great Lakes have been declining for some time. This is not to say continued work on PCBs is useless; on the contrary it can serve to confirm or refute many of the cause/effect relationships which have been alleged for years but which cannot be proven rigorously within the Great Lakes themselves. PCBs are also much less readily metabolized by vertebrates than are PAHs, and hence it should be easier to keep the Ah receptor occupied with PCBs than with PAHs.

The environmental toxicology of dioxins and furans is growing at an incredible rate, but an experiment with these materials might be very difficult to do from the standpoint of the exposure of personnel doing the experiment, and especially from the standpoint of obtaining the necessary approvals. As toxicants to occupy the Ah receptor and keep it blocked, these would be the best compounds of all.

The environmental toxicology of PAHs is much less well understood, particularly those associated with industrial discharges and LRTAP. They persist in sediments but have little tendency to accumulate in vertebrates because those animals metabolize them to polar compounds and excrete them. They do accumulate to a greater degree in some invertebrate animals which lack the enzyme systems to metabolize them. If PAHs are used in the Lake 375 experiments then some additional thought will have to be given to the dosage and type of mixture used.

Need for future cleanup

The agreement with the Government of Ontario requires that the lakes be restored to their original state after experiments are completed. That may not be possible with any of these compounds, however, with PAHs there will not be accumulation in the top predators as there will with either PCBs or TCDD/TCDF. Consequently there will be less concern about

material remaining in the lake for a long period if it does not reach the species of interest to sports fishermen.

Fundamentally we have to decide whether we are doing a pathways experiment or an effects experiment. If we use PCBs we will be doing mainly an experiment to verify knowledge and hopefully add some new knowledge on the environmental fate of PCBs; the main biological outcome will be a rigorous test of the hypothesized cause/effect relationship between PCBs and reproduction in fish, and between sub-lethal effects and population effects. The same will apply to PAHs except that the information will largely be new instead of confirmatory.

[1]**Editor's Note**: *There was considerable debate about the adequacy of current regulation and existing knowledge on PCBs in the discussion that followed this presentation.* *See the PAH vs PCB debate on page 20.*

Group 3: Population and Ecosystem Level Effects. Tuesday Morning Report

Chairman: Dave Schindler, University of Alberta
Rapporteur: Ken Mills, DFO Winnipeg
Uwe Borgmann, DFO Burlington
Laird Shutt, CWS Hull
Vic Cairns, DFO Burlington
Doug Dodge, OMNR Toronto
Wayne Fairchild, University of Manitoba
Al Johnson, OMNR Rexdale
Bob Hecky, DFO Winnipeg
David Lean, DOE NWRI
Diane Malley, DFO Winnipeg
Chip Weseloh, CWS Burlington

We decided that it should be an ecosystem experiment not a fish experiment. Pathways information is needed to run models. We reached identical conclusions regarding the addition as did Group 1. We want contaminants in both the littoral and profundal zones. The contaminant should be put in on a solvent. There should be intensive work on key species. We recommend oversampling and archiving samples. Sampling small sized organisms for analysis may be difficult - we suggest doing different particle sizes.

The experiment should include birds (e.g swallows) and mammals, toads and turtles. As far a techniques are concerned we see the experiment developing new toxicological not new ecological techniques. The standard suite of ecological techniques should be applied. In terms of time frame, we are probably talking 10 years not five years.

If L375 is the choice we have lots of reference lakes. The lake trout, fathead minnow, pearl dace combination in L375 is also the most common combination in other ELA lakes.

Microbial dechlorination of PCBs may be important and should be investigated. There is controversy over whether biomagnification is really due to fat accumulation or food chain accumulation. Therefore we recommend separating lipids before PCB analysis.

A study should be done of PCBs in trout in ELA lakes to compare contemporary levels in trout which we know are insectivorous versus those which are fish eaters.

Group 4: Regulatory and Social Issues. Tuesday Morning Report

Chairman: Andy Hamilton, Rawson Academy
Rapporteur: Gord Koshinsky, DFO Winnipeg
Hugh Bain, DFO Ottawa
Donna Wales, OMNR Toronto
John Cooley, DFO Burlngton
Sandra George, DFO Burlington
Jim Morrison, DFO Ottawa
Hosein Sadar, F.E.A.R.O., Ottawa
Adam Socha, OME Toronto
Jack Vallentyne, DFO Burlington

It was perceived that Group 4 was charged to explore matters pertinent to the proposed experiment which would not ordinarily be on the scientific agenda of participants.

Discussion began with the realization that the experiment was not *a priori* feasible in the present Canadian social and political milieu. It was considered reasonable to expect, however, that the experiment could be rendered socially and politically feasible through appropriate planning, management and communication. This will require a conscious, concerted, and pro-active effort. It is not considered a "given" that this effort will succeed, and the effort itself will certainly entail a substantial and onerous dimension of the project. It is clear that this will be by far the most complicated and potentially controversial experiment which has ever been undertaken at ELA; it will require commensurate managerial and communications attention at a time when the confidence of the (DFO) scientific community in these functions is not particularly high. It is also relevant that the awareness and expectations of the general public on matters of environment and environmental science have never been more widespread and acute.

Factors of which particular account will need to be taken include:

1. A general chemophobia in the public mind (and thus also in the minds of politicians, and administrators).
2. Particular public phobias about chlorinated hydro carbons.
3. The Not-In-My-Back-Yard (NIMBY) syndrome.
4. Animal-rights and ecosystems-rights points of view.
5. The recent (1985) PCB spill on the Trans Canada Highway near the ELA.
6. Competing land and resource use considerations near the ELA.
7. Negative public perceptions about governmental competence.
8. The possibility of accidents and unforeseen consequences.

It is believed that all these factors are ultimately manageable, and that most of them could in fact be turned into support in the context of a carefully-controlled and results-oriented experiment. Positive considerations include:

1. The strong reputation of the ELA program.
2. The very localized disruption which will be entailed, compared with the extent of existing PCB deposition.
3. The broad (anticipated) base of participation in the experiment.
4. The (ultimate) remediation focus of the project.
5. The object of broad extrapolatability of the results.
6. The (assumed) commitment to keep the public apprised of the project.
7. The requirement to restore the site.

Three requirements are of over-riding importance:

1. A very concise and transparent project plan.
2. A very deliberate and careful process of public liaison.
3. A very thorough compliance with administrative, managerial, and political protocols.

The experiment will require environmental impact screening in conformity with the Federal Environmental Assessment and Review Process. This process will need to be very carefully and proactively managed. A PCB addition might require a special Order-in-Council under the Fisheries Act. Ontario regulatory requirements will need to be identified and met.

The experiment will carry some very genuine ethical considerations. It will be axiomatic that there must be consensus that the results will outweigh the negatives, and that there is no other practical way to obtain these results with lesser ecosystem stress. Participants must commit to:

1. A basic affirmation of the need to respect life, and not to stress unnecessarily.
2. A target of achieving maximum results.
3. A program of follow-through.
4. A full disclosure and use of the information.

Three over-riding ethical considerations were identified. The experiment should not be initiated unless/until:

1. There is strong consensus on what exactly is to be achieved, and how this is to be accomplished (study plan).
2. There are adequate resources in place to see it through (managerial commitment).
3. There is maximum provision to determine and deploy the results in the broadest possible context (ecosystem focus).

In terms of experimental design, it would seem worthwhile to consider:

1. Use of more than one lake; perhaps with pathways experimentation in one, and effects experimentation in another.
2. Use of limnocorrals within the study lake; perhaps with pathways studies in the lake and effects studies in the enclosures.

Tuesday Morning Plenary Session - the PAH versus PCB Debate

This discussion followed the presentations of subgroups 1 (Environmental chemistry) and 2 (Biochemical and physiological effects) in which Group 1 supported PCBs as the chemical to be used in the experiment and Group 2 proposed PAHs. The discussion was chaired by Jack Klaverkamp.

Ken Minns: We need to decide the experimental objectives (stress vs pathways) before deciding on the chemical.

Jack Klaverkamp: The contribution of ELA is knowledge on ecosystem stress. The pathways information will help in the interpretation of stress responses. The techniques for measuring stress are applied to polluted areas, such as the Great Lakes.

Peter Landrum: There is strong support for the hypothesis that PCBs are producing effects on Great Lakes biota. Levels at which PCBs induce effects are known. PCBs are not rapidly metabolized and as a result it will be possible to have an measure of exposure. The metabolism of PAH by vertebrates will make it difficult for exposure to be defined. How much chemical should be added? For PCBs we know what levels and can estimate effects. In areas where effects of PAH are observed concentrations in sediment are in the parts per thousand range. These are not levels which can be realistically put into the experimental lake. The mixture of PAH also includes N and S containing heterocycles for which we have no information. The hypothesis (of relating concentrations and biochemical and physiological effects to reproductive failure) is more defensible if we use PCBs.

Dave Schindler: What makes a good ELA experiment? The key experiments at ELA have included something that stresses organisms. We shouldn't just do a pathways experiment. We should do something that bioaccumulates rather than something toxic to a narrow group of organisms. Realistic concentrations should be used. In terms of impacts on regulations - regulations may be in place but not stringent enough to protect ecosystems. There are degrees of regulation - the present regulations for TCDD and organochlorines in Canada are weaker than those proposed in the U.S. Another consideration is that the chemical selected should be analytically realistic. Finally the selection should be something that is an international problem rather than something that presents only a very localized problem.

Kelly Munkittrick: PAHs should be the compounds selected although 2,3,7,8-TCDD would be a good choice because of its importance as a pollutant emitted by pulp mills. PAHs are associated with biological effects. PAHs are a major problem in the Great Lakes and are important on both coasts. The public and politicians won't accept that PCB information is transferable to dioxins and furans.

John Carey: There would be a problem with the quantity of PAHs, as well as dioxins or furans required for the whole lake experiment. I disagree that enough is known about PCBs. No one has done a whole lake experiment with them. The public is interested in PCBs compared to PAHs. Below the fish consumer level, PAHs may be critical pollutants but if the objective is to do a lake scale experiment answering food chain questions then this argues for PCBs.

Dave Schindler: I agree with this but prefer TCDF although I recognize the problem with quantities available. We need maximum transferability of the results.

Andy Hamilton: Group 4 (Regulatory and Social Issues) struggled with the question of what do we really want to get out of the experiment. Is it to make standards more stringent, remediation or pathways? In terms of marketing the experiment we could use lower levels of

chemical if it was pathways - this ties in with the ethic questions. If it is sold on the basis of stress, and noe is demonstrated, will there be pressure for higher concentrations? Should we be using one chemical or a group of chemicals? Maybe we need a background paper addressing what we want out of the experiment.

Jack Klaverkamp: I would just like to reiterate the value of ELA for ecosystem stress experiments. The cadmium whole lake experiment is doing good pathways work. Pathways can be built in but the purpose of an ELA whole lake experiment is to look at ecosystem stress.

Dave Schindler: Cadmium wasn't picked just for stress reasons. Generally it was the best metal for the capabilities of the Freshwater Institute labs.

Peter Delorme: I was the token ecologist who spoke in favour of PCBs in Group 2's discussions. PCBs are regulated but these is still a lot of public concern. Strategies to get rid of them are required. There are practical problems with use of PAHs.

Ross Norstrom: The PAHs that cause effects may be very hydrophobic, i.e. the high molecular weight class, but these may not be very bioavailable. A PAH whole lake experiment wouldn't really be a whole-lake experiment. It would be a water-sediment interface experiment. The pelagic component would not be a factor. The whole lake perspective would be wasted.

Dave Schindler: Similar arguments were made at the beginning of ELA about use of sewage versus a single nutrient. These arguments were also advanced in the case of acid - single acid versus a mixture. In the case of organics, maybe we can't simplify to one compound but there are concerns with use of a mixture. You don't want to mimic the mess out there. Total realism is not what ELA experiments are about.

Jack Vallantyne: I defer to Steve Eisenreich.

Steve Eisenreich: From an environmental chemical, pathways, importance and practicality points of view PAHs are not my choice. Use of just a few PCBs is also not correct. We can add PCB mixtures similar to Great Lakes and handle it analytically. Concerning the addition of co-planars with PCBs I am now convinced that this should not be done. The PCB experiment is "doable". There are still many questions about what to do about inplace pollutants. The experiment will unlock secrets about levels of effects. An incremental addition is recommended to build up the concentrations. The PCB mixture will have a trace of 2,3,7,8-TCDF which will give added realism.

Dave Schindler: Reviewers are going to pick the results apart. There could be problems with interpreting the effects of the Aroclor mixtures.

Ross Norstrom: The problems of interpretation could be handled with a rat hepatoma bioassay. This would provide an integrated measure of dioxin-like toxicity. In terms of the Great Lakes as a whole, PCBs are probably the most important compounds from a major fish standpoint. And there is no question about their importance to wildlife.

Dick Peterson: I had thought this meeting would be an expansion of work on halogenated aromatic hydrocarbons to test the hypothesis about failure of lake trout populations. Our work shows that lake trout eggs having 50-60 ppt TCDD result in early life stage mortality. PCBs may also cause this. This whole lake experiment offers, for the first time, the opportunity to test this hypothesis - that the addition of PCBs is going to produce reproductive failure of lake trout. Incremental additions can be used to determine an effects level. It is a multigeneration study, a unique opportunity. An important experiment to assess

impacts. Concerning the debate of PAH versus PCBs. Both act through the Ah receptor. PAH's also act via other mechanisms e.g. electrophilic metabolites. But we are looking for reproductive effects and to see this you need sustained occupancy of the receptor. But PAHs are metabolized. You will not get sustained effects with PAHs. What kinds of effects would we be looking for? We must optimize the experiment to see this effect. There is a better chance of seeing this effect with halogenated hydrocarbons. Not likely with PAH.

Peter Landrum: Another aspect of chlorinated hydrocarbons is that there is considerable interest in them internationally.

Steve Eisenreich: One of the potential outcomes of the experiment is that PCBs will have no effect. This would be a tremendous finding and would save millions of dollars in remedial action.

Bill Strachan: There is the question of using a PCB mixture or 1 or 2 specific compounds. The impact must be interpretable. The mixture might have an effects but would it be interpretable?
Art Niimi: There is increasing evidence to show that PCBs could have antagonistic effects. This would be an advantage of using the PCB mixture.

Dave Schindler: In designing the acid experiment there was a debate between acid alone or acid plus aluminium. Aluminium turned out to be a red herring. Similar analogs for nutrients. I am inclined to go with a simple mixture.

Peter Landrum: The rat hepatoma bioassay would permit a measure of TCDD-like toxicity. It would account for the possible antagonistic effects.

Ross Norstrom: A simple mixture or single compound would also make interpretation of the experiment difficult. With a mixture the experiment would be more realistic even if we couldn't fully interpret it.

Peter Delorme: How many congeners would be expected to bioaccumulate to high levels?

Derek Muir: The PCB mixture can be defined. An Aroclor mixture similar to the mixture in Lake Ontario sediment was proposed by our group. With a few changes in congener patterns, this mixture will also be seen in fish. For PAHs an appropriate mixture will be hard to define.

Dave Schindler: There are bigger ecosystems in Canada than the Great Lakes which are still protectable. We need to consider these also in selecting the chemical.

Ross Norstrom: We should think of PCBs as "isotopes". The patterns of the original Aroclor mixtures are out there. We can come up with estimates of Aroclor loadings from herring gull data. The Aroclors do move around as a group with some changes between trophic levels. PCBs can be treated as a single chemical with a variety of members.

Greg Brunskill: From previous ELA experience the more we can simplify the experiment the easier it will be to do both pathways and effects. In the case of acids we could have done the experiments with all acids but a single acid was a better experiment.

Al Johnson: The question that is frequently asked me is when are we going to get rid of PCBs. A lot of care and thought should be put into what happens after the addition stops and about the way recovery occurs. There are many questions about PCBs which are not understood for example, why are PCBs in Hudson River striped bass remaining high? There

have been declines in PCBs in Lake Ontario salmon in the late 1980's but we don't understand it.

George Dixon: Both experiments, with PAH or PCBs, would be valid. But the PAH experiment is premature. With the PCB experiment you have background information from which questions can be formulated. There is a concern that the toxic effects may be subtle in the case of PAHs. We haven't done our lab homework on PAHs and don't know what questions to ask.

Diane Malley: Is the ability to do only 200 to 300 analyses, mentioned by Derek Muir yesterday, sufficient? How should they be distributed?

Uwe Borgmann: This experiment is different from previous ELA experiments. The effects, if seen, will be subtle and at the top of the food chain only.

Dave Schindler: Let the toxicological/ecological results drive the analytical work. Archive the samples until it is clear which analyses will give the main results. Oversampling is a good strategy.

John Carey: You won't overwhelm the lab with lake trout samples!

Uwe Borgmann: Food chain length may have a tremendous impact on PCB levels in lake trout. I recommend a large amount of sampling at lower trophic levels. For example in Lake Ontario we need information on levels in alewife.

Dave Schindler: We might already have archived before and after food chain manipulation material from Lake 223 from before and after mysis were eliminated. We might see a food chain related effect.

Steve Eisenreich: We shouldn't be limited to 300 analyses. This is an important experiment which will attract other collaborators.

George Dixon: We shouldn't have to worry about funding. On the subject of food chains, forage fish are important.

Peter Delorme: Pathways and effects studies will be interrelated.

Dave Schindler: We could study age related phenomena in Roddy Lake population to help design how to sample the few trout in L375.

John Carey: Can the lake be sampled without altering the food chain?

Ken Mills: Yes, it can be done. We can probably remove about 5% of the lake trout population without impacting growth i.e 20 per year. The numbers of fish is a normal situation at ELA. L382 (Cadmium experiment) is unusual. For the acidification experiments the samples numbers were similar to those proposed for L375.

John Carey: Is an annual sample of 10 of each sex adequate toxicologically?

Kelly Munkittrick: What about replacing fish that are removed?

Ken Mills: I've never liked that approach. Individuals may not return to the spawning grounds. There is also the problem with sampling due to shorter exposure to the organic.

Lyle Lockhart: We would follow aspects of the sub-lethal toxicology in fish from other lakes. The time of year may be critical for some biomarkers. The samples could be size and age restricted.

Jack Klaverkamp: Some responses are chemical specific e.g. MFOs, but others are related to fish health. We have four years of temporal and spatial variability of several biochemical/physiological parameters in ELA fish.

George Dixon: Nonlethal sampling can also be done - biopsies.

John Carey: We have had problems with statistics on numbers of fish assayed for biochemical/physiological parameters in our pulp mill studies.

Bill Strachan: What is necessary to follow trends in contaminants in terms of sample numbers? Can Mike Whittle tell us?

Mike Whittle: Biomass dilution may be more significant in Great Lakes fish than at ELA. You may get the same degree of confidence in the analysis of 5 to 10 fish if age/size is narrowly defined.

Jack Klaverkamp: Do we need a lake trout "story" to improve relevance/ application to the Great Lakes?

Ken Mills: We have 17 years of data on L226, a whitefish lake. But we are currently working on 13 lake trout lakes at ELA. The techniques have been worked out for lake trout. Techniques have not been worked out for whitefish.

Ian Smith: At the IJC symposium on salmonid reproduction (Roundtable on Contaminant-caused Reproductive Problems in Salmonids, IJC, Windsor, 1990) the Ah receptor mediated toxicity hypothesis was discussed. But it became clear that the causes of reproductive failure were more complicated than that. Many factors contribute to lake trout failure but because of the large amount of contaminants data the Ah receptor hypothesis was the best developed explanation. Chemists can measure the contaminant levels easily but biologists have trouble measuring reproduction without disturbing the population. I support the focus on lake trout reproduction.

Jack Vallantyne: I am concerned about the target concentration for PCBs of 0.5 ug/g (dry wt) suggested for sediment. Many sites are 10 to 100-times that. This needs to be increased, perhaps to the average concentration in areas of concern.

John Cooley: The average PCB concentration in sediments in areas of concern would indeed be far higher than 0.5 μg/g.

Dave Schindler: I suggest starting low and doing pathways work with an intact food chain. The criteria used to decide concentrations should be environmentally realistic.

Lyle Lockhart: The toxicology will be largely wasted unless levels which cause effects are reached. We need to calibrate sublethal responses. A decision should be made annually on concentrations.

Kelly Munkittrick: We have dismissed PAHs. Lets go back to the working group discussions in separate rooms.

Reports from Groups 3 (by Dave Schindler) and Group 4 (by Gord Koshinsky) were presented. Further discussion followed:

Andy Hamilton: There is a need for a clear statement that can be communicated to the public at large. It should be part of a communications package. This is not meant in a negative way. We must think through what we want to get out of the experiment.

Diane Malley: The cost effectiveness of the experiment can be stressed.

Ross Norstrom: You should consider bringing environmental groups onside.

John Cooley: Great Lakes United would be one of the important groups in this part of the world.

Dave Schindler: Environmental groups such as Greenpeace and the Sierra Club should be made aware of the experiment. The Pulp and Paper Workers union are potential allies.

John Carey: Before going public you will need to have a defensible remediation plan which would at least state the long-term fate, impacts and geographic area involved.

Ken Mills: There is a public perception problem with some ELA studies now. There has been trouble getting a fish collectors permit and debates among district OMNR and OME.

John Cooley: At the Federal-Provincial level we should work through COA (Canada-Ontario Agreement) at an early date. Seize upon the "partnerships" theme. Ontario may even join in the study. The provincial government should feel some ownership of the study.

Al Johnson: The responsibility for issuing the permit ultimately rests with the local district.

Dave Schindler: You should not make deals at high levels in isolation from the local level.

Al Johnson: It should be recognized that local staff rotate and there will be a need to "re-educate" new staff about the experiment.

FINAL REPORTS OF WORKING GROUPS

Group 1: Environmental Chemistry, Final Report, Tuesday PM

Our group reached a concensus on a number of points although we did not have time to consider all the questions in detail.

The chemical: Chairman, Steve Eisenreich, asked if there was a concensus within the group on the chemical. Group members agreed unanimously that PCBs were the chemicals to be studied. A PCB (Aroclor) mixture was the most practical form of the chemical. The idea of an artificial mixture was rejected.

There was much discussion of the composition of the PCB mixture. An Aroclor 1242:1254 (1:1) mixture would be characteristic of Lake Ontario sediments, except for surficial sediments. The experiment will enable the testing of the hypothesis that Aroclor mixtures are not greatly transformed in lake sediments. With the higher level of 1242 the more bioaccumulation may be expected. Other locations e.g. Southern Lake Michigan, U.S. east coast and the Baltic have PCB patterns explainable with various 1242:1254 combinations. It was suggested that Aroclor 1260 also be added because higher molecular weight congeners are important in areas of concern in the Great Lakes. In conclusion, a mixture of 1242:1254:1260 (1:1:0.5) was recommended unanimously.

Method of addition: A consensus was also reached on the method of addition. Various strategies were discussed during the Monday PM and Tuesday AM sessions. The idea of adding the organic contaminant on particles, which was proposed in Derek Muir's "strawman" design, was rejected. There was concern that we could not duplicate the kind of particles found in the water column and that particles might be selectively bioavailable to filter feeders.

Injection of an acetone solution at about 1 mL/min into hypolimnetic waters (about 10 m depth) in the fall just before lake turnover was recommended. A back of the envelope calculation suggested that about 90% of the PCBs would be in solution in the lake water. Water exchange with the lake sediments would ensure that about 99% of added chemical would be in littoral and profundal sediments within one week. The proposed mode and timing of addition would not over contaminate the littoral zone as might occur from a epilimnetic addition.

There was some discussion of sampling protocols to follow the dispersel of the added chemical. The use of SF_6 was proposed. However a soluble gamma emitter, e.g. ^{22}Na and a particle reactive isotope such as ^{60}Co were suggested as tracers for the addition.

Amount to be added: Calculations by Bill Strachan indicated that 3 kg would be required to achieve 0.5 μg/g in sediments. This assumed 10.3×10^4 m^2 sediment area (i.e. at 10 m depth) with a volume of 5100 m^3. Assuming a Kd of 10^5 (low but limiting case) 84% of PCB would be in sediment, i.e 2.5 kg/5100 m^3. With a Kd of 10^5 water concentrations would be 500 ng/L. A higher Kd, 10^5 was thought more realistic by other members of the group, would yield proportionally lower water concentrations, i.e 6 ng/L and slightly higher sediment concentrations (0.6 μg/g for 3 kg addition). It was suggested that 1 kg be added initially.

The final discussions concerned environmental chemistry measurements to assure a mass balance, process-related information and detailed food chain transfer data. For the mass balance a precise measure of input would be required. PCBs could be lost in the delivery system. However the tracers will help check this. Measurement of PCBs on sediment,

suspended solids, sedimenting particles and water will be required to assure mass balance information.

Sediment traps: There was discussion of the need for a preservative to reduce biodegradation of the organic carbon. Sample size will be small but ug/g levels on sedimenting particles would be expected. If sample size was a problem for analysis, samples could be composited. Mass, organic carbon, PCBs and radiotracer information would be need from sediment traps. Monthly or seasonal sampling was recommended. The measurement of upward flux of contaminants using downward facing sediment traps was proposed by Greg Brunskill as a separate experiment.

Sediment: Steve Eisenreich proposed that two large cores be collected, one in the deep southern basin and one in the northern basin. In addition 50 small cores from approximately 0 to 5 cm depth be collected with the aid of scuba divers. These would be composited and subsamples analyzed. The combined data would yield estimates of the mass in lake sediments.

Water samples: Water samples at the outflow would be essential. A weir at the outflow was highly recommended. A vertical profile should be done on both dissolved and suspended chemical. Probably only 5 to 10% of PCBs in the water column will be on particles. Sampling and analysis of suspended solids for e.g. separation by continuous centrifugation, was recommended. Discrete water bodies, i.e epilimnion, hypolimnion, should be sampled. A detailed water column survey should be performed at least once annually. The use of solvent filled dialysis bags to obtain an integrated measure of the dissolved phase.

Characterization of the PCB mixture: Full characterization by several independent labs was recommended. This would include the content of furans and coplanar PCBs. A full suite of PCBs should be analyzed, i.e including co-planars, on at least one full set of samples, once per year. Some of the original spiking Aroclor mixture should be archived. The PCB mixture used in the Green Bay study was recommended for all lab involved. The QA/QC protocol used in the Green Bay study was recommended for use in the study to assure agreement among participating labs.

Food Chain: The main recommendation of the group was that attention be paid to the benthic component. There was not enough information on the individual components to suggest which organisms be sampled. An early spring sample each year would be useful because it would be an integration of the previous fall application. Because of the availability of fathead minnows they should be sampled several times annually. Benthic invertebrates should be sampled seasonally at a minimum. Sampling of lake trout will be dependent on the fishery work. It was noted that analysis of trout eggs would be important.

Group 2: Biochemical and Physiological Effects, Final Report, Tuesday PM

Following resolution of the PAH versus PCB question in the plenary session Tuesday morning, the group continued with a slightly different mix of participants than on Monday.

Ross Norstrom gave an explanation of the use a chick hepatic cell assay which functions in much the same way as the rat H4IIE cell line. The chick cells offer the use of two endpoints, ethoxy resorufin-0-deethylase (EROD) induction and porphyria. CWS may be able to provide some assays of this type to participants in the experiment, or they can help people adapt the assay in their own laboratories. The chick cells offer some advantages over the rat hepatoma cells in terms of sensitivity and ease of handling. It was generally agreed that one of these assays which are sensitive to overall content of Ah receptor-active compounds should be included in the design.

It was pointed out that impacts on lake trout reproduction are not well understood. The polyhalogenated hydrocarbons may well be responsible, the matter cannot really be settled without an experiment of this type.

There will be a need to examine the potency of the PCBs in the mixture relative to that of TCDD in terms of the biological responses actually being monitored in the experiment. The relative potencies may not be the same for fish as for mammals, and they may not be the same for other responses as they are for AHH induction. For example, in the lab Dick Peterson consistently sees blue sac disease but that does not turn up in field populations even though the TEFs are higher. It is necessary to examine embryonic stages of fish.

It is essential that the exposure be taken high enough some time during the experiment to generate population effects. This is the only way we can tell how the sub-lethal biomarkers are related to recognized ecological effects.

In work with rats the foci of interest include the hypothalamic-pituitary-gonad axis. Exposure for a short time during early development results in signs of thyroid deficiency; offspring are normal except for the inhibition of secondary sexual development. These effects occur at dosages greater than two orders of magnitude lower than those required to produce overt adult toxicity.

CWS would be interested in adding some ducks (wings clipped) to the lake, and also in tree swallows and redwing blackbirds. They will analyze samples in their biomarker lab in Hull for histopathology of liver and thyroid, liver inducible enzymes and for retinol. This summer they would like to survey the lake and see whether some studies of toads, turtles and small mammals (mink) might also be possible. They will need data on PCBs in emergent insects since those are the food source for the swallows. Similarly they will need residues in the foods used by the ducks.

The benthos has been done relatively poorly in Lake 382 and the mass balance suggests that benthic organisms are likely to experience higher exposures than pelagic ones. The same can be predicted for the Lake 375 experiment, and so it is important to put in place good benthic studies at the beginning. The fish habitat research section hopes to be staffing a vacant position for a scientist interested in benthos.

The experiment opens the possibility of doing challenge experiments in which fish from the lake treated with PCBs are challenged with other toxicants (notably those which act through the Ah receptor) to define interactions.

Studies which should be included (no priority implied)

1. Exhaustive characterization of reproduction by **all** species of fish in the lake, including MFO, thyroid, gonad, etc. All samples need not be analyzed but should be taken and archived until either the residues or the population data suggest that a response should be present.
2. Residues in several tissues will have to be determined (liver, gonad, eggs).
3. Pharmacokinetic and dose/response laboratory experiments are needed. This should include reproductive studies on eggs which have been produced by treated mothers.
4. Lipid peroxidation. A proposal received from V. Palace and J. Klaverkamp. It is known that lipid and carbohydrate metabolism is affected by some compounds acting through the Ah receptor, and so work of this type should be included.
5. Immunosuppression. It is not certain how important this will turn out to be. It was suggested that it may not be as important for fish as it is for mammals, however, the tests being used are mammalian in origin, and they may not be optimal for fish.
6. Pathology. There is no doubt that pathologies will be found by electron microscopy that are not visible by light microscopy. If someone can be found to add the EM capability it will be worthwhile.
7. Genetic effects. Many (over 450) species have become resistant to agricultural pesticides including DDT which has some structural similarities to PCBs. Any trend to do this should be determined by annual dosage/mortality lines with a suitable aquatic insect.
8. Linkages. The linkages among biochemical/physiological effects and population effects are probably the most important outcomes of the experiment.

Group 3: Population and Ecosystem Level Effects, Final report, Tuesday PM

Is this an ecosystem experiment or a fish experiment?

This is an ecosystem experiment; it must be an ecosystem experiment to adequately describe pathways as well as adequately measure stress. The pathways are necessary to model results in a meaningful fashion. In past ELA whole lake experiments, the unexpected (and frequently some of the most important) results are detected only because the experiments were designed as whole ecosystem experiments. An additional argument for adequately addressing all trophic levels is that we could potentially differentiate between food chain accumulation versus sediment/water based accumulation. We may also observe different PCB congenors at different trophic levels.

We should consider adding trophic levels above lake trout. For example, we might consider further research on effects for amphibians, tree swallows, ducks, and mink. These levels bioaccumulate rapidly. We may observe different uptake patterns in these organisms compared to lower trophic levels. There may be opportunities for collaboration with the Canadian Wildlife Service.

What taxonomic groups/species should be monitored for population level changes?

There must be a balance between extensive research on all groups and intensive research on targeted organisms. In particular, organisms related to the food chains ending in the fish species should be targeted. As well, Mysis relicta is an important indicator that should be given particular attention.

There is no doubt that lake trout should be targeted for specific activities, but only within the constraints that the population abundance allows so that there are minimal impacts from

research-related "exploitation". We should take advantage of opportunities to monitor pelagic versus benthic food webs, if these opportunities are present.

Do we need the same level of effort for all groups or what level of effort is sufficient for specific groups/species?

Obviously it is desirable to have intense effort at all trophic levels, but it would be prudent to stratify our effort given the potential resources to support the program. In general, we should oversample appropriate trophic levels and archive the samples for analyses later, when these analyses appear warranted. This is done routinely for zooplankton at the ELA; it could also be done for benthos.

We should consider stratifying "water column" samples by particle size: 0 - 20, 20 - 200, 200+ microns. This appears particularly important given the distribution of dibenzofurans in the tube experiments conducted in Lake 375. The picoplankton appear particularly important for organic toxicants in the Great Lakes; we should address this group carefully to delineate food web uptake.

We can make pretty good guesses on the taxonomic groups/species to monitor closely prior to the experiment. We should also guard against the attitude that we will monitor a species/group just because we have the capability/desire to monitor that species/group independent of likelihood of being affected.

Because we expect the sediment route of uptake to be important, we should target organisms closely associated with sediment for particular attention.

At what life stage(s) do we anticipate changes? Is it possible to detect changes in population parameters (growth, survival, abundance, etc.) if they actually occur?

We expect changes either in very early life stages or in reproductive potential (quality) for various species. It is more difficult to identify whether we will detect subtle changes in population parameters. If there are complete reproductive failures, we will be able to detect these effects.

Are there potential "indicator" species we should target for more intense studies?

There are indicator species we should target for special studies. Mysis relicta should be emphasized, as well as periphyton, fathead minnow, crayfish (mixed discussion on value of crayfish), benthic insects, turtles, frogs.

What reference lakes should be used for biotic studies and is it necessary to maintain the same level of effort for reference (control) populations as for similar groups (species) in the manipulated lake?

It is hard to generalize an answer for this question. In past experiments at the ELA, we have conducted studies on multiple reference populations for most trophic levels, not depending on single populations for comparisons to those in experimental lakes. This is the most prudent approach, especially considering the problem of pseudo-replication.

Lake 375, the proposed experimental lake, has biota typical of a wide range of ELA lakes. In addition, we are already monitoring lakes similar to Lake 375 in size, depth, and communities. The lake trout, white sucker, minnow, slimy sculpin fish community is typical of a large number of lakes where we are already conducting intensive studies.

We already have up to two years background data for many components of the Lake 375 biota, but there are gaps for certain components of the biotic community. We should move quickly to fill these gaps in the upcoming two years prior to additions.

How do we relate changes in laboratory studies to population level changes? How do we relate cellular, tissue, or organ level changes to population-/ecosystem changes?

These are related questions. Part of the purpose of the experiment is to relate cellular, tissue, organ level changes to population/ecosystem changes. There should be careful integration of parameters measured in field populations with those from previous and ongoing laboratory experiments. In particular, preservation of samples in the field must conform to standards for laboratory analyses. We should take advantage of any previous laboratory bioassays to both predict changes in lake ecosystem and as a guide to collection of relevant data during the experimental additions/recovery.

What potential collaborations are necessary to ensure that essential studies are completed?

There is obviously great interest in this experiment by many university and government groups. There should be extensive collaboration between staff at the Freshwater Institute with those in Burlington (such as at this meeting). In addition, we should keep interested university and government researchers of progress during the experiment to ensure potential collaboration.

Is the present time frame of the experiment adequate?

The present five year time frame for the experiment is too short. It is necessary to use environmentally realistic concentrations for additions. It is also necessary to bring lake sediments into equilibrium with the additions prior to the subsequent recovery phase of the experiment. Most ELA whole lake experiments take place over (at least) ten year periods. Decisions to raise contaminant levels in these experiments are not made according to rigid experimental schedules; they are made after careful review of results for each year of study.

Application method

The method of contaminant addition should be chosen carefully to maximize the potential for detecting food web transport of the PCBs. It should also not be timed to coincide with fish spawning or other key periods for members of lake community.

Group 4: Regulatory and Social Issues, Final Report

1. Feasibility: social, political, scientific

It had generally been assumed and was further corroborated in the course of the workshop that the proposed experiment was scientifically feasible given appropriate attention to experimental design and execution. The Working Group came to the realization and consensus that social and political feasibility could be assured as well through appropriate planning, management and communication. These matters will require a conscious, concerted and pro-active effort, however. The Working Group focused its attention on identifying the components which would be integral to such an effort, and exploring how they might be actioned and achieved. The questions which were posed to the Working Group by the Workshop organizers served as a reminder and as a guide for these deliberations.

A number of factors were identified which could pose impediments for the experiment. These include:

a) Environmental consciousness, in the parochial sense, on the part of the public. This is the attitude which, while perhaps (but not necessarily) recognizing the basic worth of such an experiment, might query, "Why do it here"? This is commonly referred to as the "Not-in-my-backyard" (NIMBY) syndrome. While a common trigger for this syndrome has been the importation of waste materials into an area for disposal or treatment, it could be expected to have some expression also in respect to the deliberate introduction of a toxic substance into an experimental lake. The phenomenon could be fuelled in the present instance by the general chemophobia which is currently believed to exist among the public. Left unchallenged or uncorrected, such public attitudes can become similarly manifested in the minds of politicians and administrators.
b) Particular public phobias about chlorinated hydrocarbons. At issue here is a perceived focusing by the public of the more general environmental concern, this in respect to the chemical or group of chemicals of choice for this particular experiment.
c) Animal-rights and ecosystem-rights points of view. This could extend to encompass opposition to subjecting wild organisms (in a lake) to experimental treatment.
d) The recent (1985) PCB spill on the Trans-Canada Highway, at Kenora. This accident occurred near the ELA turnoff, and may have sensitized the local public to the dangers posed by this chemical.
e) Competing land and resource use considerations near the ELA. The area is held in reserve, so that any such conflicts would be more perceived than real.
f) Public perceptions about governmental (especially DFO) competence. The public may take negative cues from any number of unpredictable events involving government. Perceptions about such controversies as DFO management of the east-coast groundfish fishery are potentially negative factors in public perception and attitude to DFO activities.
g) The possibility of accidents and other unforeseen consequences.

None of these perceptual impediments, either singly or in combination, were considered insurmountable as regards the proposed experiment. In fact, in view of what the experiment aims to accomplish, it should be possible to turn many of these concerns to advantage and support through a process of accurate and sensitive communication. Thus, for example:

- Environmental consciousness in the public should be fertile ground for creating recognition and support for the potential which the experiment offers for realizing a wide range of environmental benefits.

- The unique potential of the ELA to contribute to the resolution of a problem which has local, regional, national and international dimensions could be a source of local and regional pride and a strong basis for developing "philosophical partnerships."

- Although "governments" in general may currently be viewed with considerable cynicism, polls indicate that a much more positive view prevails as regards scientists (including government scientists), who will after all be conducting the experiment.

- The credibility of the ELA program can be demonstrated in a particularly positive light, for example in respect to achievements and influence in phosphorus controls and acid-precursor emission controls.

2. Liaison: A crucial dimension of the experiment

Appropriate liaison will be essential in the early (preparatory) stages, to gain acceptance and approval. It will also be necessary as an ongoing activity, to maintain the support of allies and to head-off uninformed negative opinion and reactions. An appropriate liaison program will have two facets, which will inter-relate:

a) With the public, and
b) Government/political, which will take cues from (a)

In respect to the public aspect, the local perspective is deemed most fundamental and important; in fact the local viewpoint is probably the only public perspective that will really be influential. This aspect needs to take account of the general populace, Indian bands, Fish and Game associations, trappers, outfitters, local businesses, and (in short) anyone with any type of interest in the ELA area. The government/political aspect needs to cover all bases, but must include (especially) local/regional levels. It will be particularly important to sequence discussions with a view to the sensitivities of vertical lines of authority as well as horizontal spheres of influence.

The need for a formal public liaison mechanism was recognized, presumably some form of advisory committee. Such a committee would be a vehicle for public input and participation. It should be locally-based primarily, and should have the participation of local OMNR office(s), at/before inception of the experiment, to provide the necessary "window" to "activist" groups such as environmental associations, Indian bands, and Fish and Game clubs.

Such a committee should be clear about "whom it is advising" (this could be a composite function):
- the public?
- participating scientists?
- project managers and administrators?
- politicians?

In addition to this formal liaison mechanism, opportunities will also need to be identified and cultivated to interact and liaise, especially on the local level, with newsmedia, schools, the "person in the street". This can be pursued by such means as tours of ELA in general, and of the experiment in particular, and by participation by Project staff in local events and celebrations. The guiding theme throughout must be to think globally, and/but to act locally.

A special need was identified and recognized to involve the Government of Ontario specifically, preferably as clear partners and/or stakeholders in the experiment. The present agreement between DFO and Ontario OMNR regarding control of the ELA program area will need to be examined to ensure that it will accommodate this experiment. The context

for consultations (with Ontario OMNR) could be provided through the Canada-Ontario Fisheries Advisory Board (CONFAB), and/or the Canada-Ontario Agreement (COA) for Great Lakes Water Quality. The need was recognized to involve all levels of the provincial government simultaneously, but that local levels should be treated as "firsts among equals".

It will also be necessary to consult, both at inception of the experiment and throughout, with the provincial and federal Environment departments. The endorsement of such agencies as the Great Lakes Fishery Commission, the International Joint Commission and Great Lakes United can reasonably be expected since such agencies are natural allies, and such positive expressions should be actively sought.

3. Information/communication

The following considerations for an information campaign were identified:

- Needs to be planned and managed.
- Cannot be left to chance or circumstance.
- Cannot be simply "allowed to happen".
- Needs to commence very early: as soon as there is basic agreement that the experiment will take place and what the general form of the experiment will be.
- Would generally look to "communications people" (in-house, or specifically hired) to provide guidance and leg work.
- Would be founded in a "communications package", which needs to be developed.

This package must be proactive, and must indicate the context of the experiment, in relation to such realities as:

- The extent of PCB accumulations already in the environment, including in ELA lakes (which, it must thus be recognized, are not pristine);
- The extent of current PCB ongoing deposition, both locally and on a broader scale.
- The apparent lack of harm to the family members who suffered short-term exposure during the 1985 highway spill of PCBs at Kenora.
- The dilution of the proposed treatment in the lake downstream of the lake to be actually treated.
- The target levels for the experiment, in comparison with regulatory guidelines and with existing levels in polluted areas.
- the small absolute amounts of material to be added to the study lake.
- the small scale of the biological populations to be affected.

It must indicate local and regional benefits and opportunities:

- For environmental protection, rehabilitation and management
- For the local economy (via generation of local "business")
- For local employment (in conducting the experiment)
- For learning
- For training scientists.

It must also identify broader benefits, including:

- Enhanced knowledge as an input for generating broad public awareness of contaminant problems and solutions.
- Enhanced public awareness along with improved technical models as a basis for national and international policy to address contaminant issues including issues related to curbing of discharges.

- Enhanced technical capacity to address control of contaminant influxes and remediation of contaminants-in-place.

It should stress:

- The broad base of participation in the experiment (assuming that this will indeed be the case): scientific, managerial, corporate/private, NGOs.
- The unique interdisciplinary research opportunity which the experiment affords.
- The expected transferability of the knowledge gained, both in terms of experimental methodology and results/applications, to other contaminants (especially other organochlorines).
- The possibility of actually testing remediation strategies in the final stages of the experiment.
- The (ultimate) remediation application of the project output.
- The lack of genuine options: the impossibility (for example) to manipulate Lake Ontario in a controlled manner. The impracticality (this needs to be elaborated) of trying to do the study in a lake(s) already severely contaminated. This also implies a need to identify exactly what will be lost or foregone if the experiment is not done.
- The restoration requirement vis-a-vis the experimental site. This should be pro-actively expounded, as a "restoration vision".
- The commitment to monitor and advise the public as well as the scientific community of experimental results, passive recovery and/or active rehabilitation of the site.
- The strong reputation of the overall ELA program.

A number of possible avenues were identified, besides "ordinary" departmental communications programming, which might be recruited as "information vehicles" for the project. These include:

- The Rawson Academy's Water Watch (especially the Profile page)
- The Great Lakes Reporter
- The Centre for the Great Lakes (newsletter)

Some very specific pitfalls were identified which require concerted avoidance or deft treatment. These include:

- Terminology. It is imperative to avoid (and if they are encountered, to challenge) such constructions as "killing lakes", "sacrificing lakes" or "dumping toxins into lakes". The emphasis should be that this experiment is a carefully controlled treatment of a lake.
- The Great Lakes perspective of "Is it realistic that this work be done outside the Basin?"
- Any local perspective of "Why is this Great Lakes work being done here?"
- The question of "Why is yet *another* study required?"
- The possibility of accidents.

Responses to such matters need to be worked out and established ahead of time, via appropriate contingency plans. Appropriate contact individuals need to be identified and briefed, but all study participants should be able to provide informed and constructive dialogue and response.

4. Governance and management of the experiment

This experiment, by its nature, poses a greater need than did previous ELA experiments for an effective marrying of science execution and science management. This is because of its greater sensitivity, complexity, and certain potential dangers. A clear, coherent, comprehensive, and transparent experimental plan and design will be absolutely vital. Broad scientific participation should be encouraged based on this plan. Scientists should develop

the plan *before* any specific participation is confirmed. Broad participation will provide a form of insurance against "capricious" political interference. The experiment needs to be seen to be (and actually must be) "manageable". Accountability will need to be a strong consideration and point of emphasis throughout.

The need is envisaged for a "Committee of Scientific Participants" (Technical Management Committee) to develop, adjust and implement the scientific aspects of study design. A major function of this committee would be the identification, selection, and prioritization of study components and study participants, along with the allocation of "allocatable" study resources. In fact, the diversity of (anticipated) funding sources is one of the main reasons why such a committee is required.

More specifically, this committee would be charged to:

a) Identify the specific set of operational questions that are to be answered by the experiment.
b) Define the data requirements to answer those questions.
c) Define the experimental procedures to obtain those data.
d) Define the uncertainty limits which are going to be tolerated.
e) Define appropriate protocols for quality assurance and quality control.
f) Define protocols for provision of and access to common data sets and to common scientific and ELA logistical services.
g) Schedule and oversee the publication of results, especially to the extent that results are published in groups of papers or reports.

The committee would exercise its role in the context of scientific coordination and integration. (*Note: This requirement is not to be confused with ordinary peer review of study components. Such will be expected to proceed according to ongoing schedules which will be arranged according to needs and opportunities.*)

5. Bounding the experiment

Considerations must include:

- Selection of target levels of the introduced contaminant that can be specifically related to existing guidelines, standards, and/or levels elsewhere (e.g. in the Great Lakes).
- Imposition of minimal downstream and incidental effects.

Commitments must include:

- Commitment to adequately support the project over a sufficient (at least 10-year) time frame.
- Commitment to rehabilitate/restore the affected (experimental) ecosystem to the extent possible.
- Commitment to monitor and report the condition of the treated ecosystem, to the public as well as to the scientific community, on a regular basis: during treatment and during recovery/restoration.

A clear definition of experimental objectives will be required. It needs to be made very plain, for instance whether the focus of the experiment, in terms of primary anticipated application of the results, will be in respect to pathways/effects, or prevention/remediation.

There was considerable and unresolved debate in the Working Group about what experimental objectives would be ultimately most useful and hence most appropriate. For example, a strong focus on pursuing the science of remediation (i.e. removal or

"decommissioning" of in-place contaminants) may be socially and politically attractive (and perhaps even essential), but would it be realistic? Perhaps demonstrating the need for prevention (i.e. control of effluents) is the more useful and more fundamental context, and perhaps not so much as regards the particular contaminant of choice per se, but as a demonstration for extension to other not-yet-suitably-regulated contaminants. According to this (latter) perspective, working to eliminate in-place contaminants one-by-one is a "no-win proposition", and the important goal is to develop hard information to support zero-discharge of all contaminants (or at least of organochlorines). The perspective which is actually adopted in this regard will have implications for target concentrations/loads in the experimental design. Is it necessary to demonstrate effects (as a key input to prevention), or is it adequate to elucidate pathways (as a key requirement for remediation)? These and other related matters must be completely settled at the outset, so that communication and liaison can be developed accordingly and pursued consistently. These questions have both managerial (socio-political) and scientific (feasibility) dimensions and cannot realistically be resolved from any single perspective.

6. Ethical considerations

The following requirements were recognized as "givens":

- There must be an affirmation of the commitment of participants to:
  - Respect life
  - Not stress an experimental ecosystem unnecessarily.

- There must be a general commitment to:
  - Obtain maximum results from the project
  - Follow through with the work over an adequate time frame
  - Not start the work, without adequate resources in place or assured
  - In fact, study the *whole* ecosystem, including terrestrial components, as appropriate and feasible
  - Link the experiment to other relevant research and experimental protocols, both underway and completed
  - Share/use the information to the maximum extent possible
  - Give full consideration and assessment to alternatives. (This requirement Will also be integral to the EIA process).

- There must be a consensus that:
  - The results will be worthwhile
  - There is no other practical way to obtain the results while invoking lesser ecosystem stress.

In summary, it was perceived that ethical considerations demand that there be:

- A strong consensus on what exactly is to be achieved, and how this is to be accomplished (study plan).
- Adequate financial resources, as well as manpower and expertise, in place or assured to see it through (managerial commitment).
- Maximum provision to undertake the experiment and to deploy the results in the broadest possible context (ecosystemic focus).

The impracticality of obtaining a *firm* long-term resourcing arrangement in a governmental context was recognized. It was considered that, if the long-term implications were openly and forcefully disclosed, it would be reasonable to interpret approval to commence as an adequate (implied) commitment that resourcing would be sustained. It is very unlikely that the organochlorine contamination problem will cease to be an issue within the time frame of

a reasonable experimental design. Accordingly, ongoing public and/or administrative pressure can be expected in support of continuing the experiment throughout its reasonable course.

7. Environmental impact assessment: "Permission" for the experiment

It was noted that PCB additions are not presently regulated by DFO. The addition of a deleterious substance such as PCBs to a lake would probably require a specific Order-in-Council under Section 36 of the Fisheries Act. A cost-benefit analysis would be integral to seeking such an Order. The shared (DFO/DOE) jurisdiction for Section 36 as regards zero-discharge poses a requirement to involve DOE in this (managerial) part of the process. The initiative currently underway to designate the candidate lake (L375) as a formal sanctuary could possibly be ill-advised; sanctuary status might preclude active experimentation. OMNR officials at the local level, however, have indicated that sanctuary status was the only practicable means of enforcing a prohibition against angling in the lake. The Nogies Creek sanctuary (in Ontario) may be a useful model. This question needs to be resolved.

The project will need to be screened via the Environmental Assessment and Review Process (EARP). It will also need to satisfy any Ontario regulatory requirements. Screening, of course, does not *a priori* lead to an EARP panel. In fact the screening process, if appropriately and effectively managed, should ensure environmental protection requirements are met without embroiling the approval process in a large, costly and time-consuming controversy. The goal should be a process which is as simple and straightforward as possible, without need for process reiterations. An EARP panel would inevitably confirm the need for information which, were it available and had it been presented in the course of initial screening, might have precluded the panel process. For purposes of screening it will be necessary to be clear about, and then to emphasize, the ultimate experimental objectives:

- If remediation, then to stress application of the experiment to currently-contaminated situations.
- If prevention, then to stress the need for the experiment to develop information to support the concept of zero discharge.

The documentation for screening will need to be as specific as possible about restoration - plans and objectives for the experimental site. The challenge will be to elaborate this despite the fact that remediation methodology per se is a hoped-for output from (rather than an available input to) the experiment.

The screening process will need to be preceded by a careful and deliberate screening plan, which lays out the various steps in the procedure and identifies who needs to do what by when. The screening process needs to confirm and credibly declare a lack of significant public concern, if a formal Panel is to be avoided. This implies a need to incorporate public participation during the screening process. This would aim to identify and address any incipient public concerns at an early stage. Such concerns might be expected to emerge in regard to such matters as:

- What might be the consequences of people drinking water from the treated lake?
- What might be the consequences of people eating fish from the lake, or consuming wildlife which has been associated with the lake?
- What might be the consequences for associated wildlife per se, including migratory birds and protected species?

The screening process must embrace all aspects of the project, including:

- Acquisition and transport of the chemicals for treatment
- On-site storage of these chemicals
- Disposition of containers and other contaminated materials
- Ancillary scientific procedures, such as use of radioactive tracers.

It might be advantageous and appropriate to make arrangements for (or at least to invite) representatives of concerned groups to observe the experimental treatments. This presumes cultivation of trust and a sense of partnership in advance.

8. Some "completely unsolicited" observations about experimental design

a) Will the experiment be designed to demonstrate pathways, or effects?

If the experiment if designed to demonstrate pathways primarily:

- A PCB mixture is the best candidate chemical
- Experimentation with more than one substance concurrently may be possible.

If the experiment is designed to demonstrate effects primarily:

- Experimentation with more than one substance would be impractical
- Higher concentrations would tend to be needed.

b) Hybrid experimental design possibilities would include:

- Study pathways in the experimental lake per se; study effects (concurrently) in limnocorrals.
- Study pathways in one lake; study effects (concurrently) in another.
- Study pathways and/or effects in the experimental lake; study remediation (concurrently) in contained mesocosms.

c) The study design must include realistic provision for:

- Adequate background observations prior to commencement of treatment.
- Scientifically credible reference/control systems, for concurrent observation.

d) Considerations:

- "Politically acceptable" concentrations may effectively preclude realization of effects. If so, the project might as well be declared as a pathways experiment at the outset, and planned on that basis.
- The probability of accidents or other unfavourable occurrences will increase in proportion to the number of treatment events.
- If pathways were the declared focus, any occurrence and demonstration of effects would be a bonus.
- If the project is declared to be an effects experiment and no effects are demonstrated, credibility will be eroded, both for continuation of this experiment and for any future work at ELA.

e) Will the experiment be for remediation, or for prevention?

This is not an isolated question; it is related to (a). In resolving this fundamental question it should be considered that credible remediation will almost certainly depend

on pathways knowledge, since it will require "going into league" with food chain (carbon cycling) and other biological processes. In other words, it might involve manipulation of such things as algal nutrition, forage species availability, bacterial processes, or benthic activity.

9. General conclusion

The managerial dimensions of this experiment will not be trivial. They will require the same devotion to excellence as the scientific dimensions, along with an adequate level of effort if the experiment is to be a success.

ACKNOWLEDGMENTS

Special thanks are extended to Joan Leatherland (Fisheries and Oceans, Burlington, Ont.) for making arrangements for meals, meeting rooms and hotel bookings which ensured the smooth running of the workshop. We also wish to thank Sharon Ryland and Carol Catt for typing and editing portions of the text and Scott Brown, Jack Klaverkamp and Gordon Koshinsky for helpful comments.

APPENDIX 1. Detailed Workshop Program.

Monday, January 7th

Opening remarks - John Cooley, Director, DFO Physical and Chemical Sciences

Introduction - Jack Klaverkamp - DFO Winnipeg (Chairman)

Bob Hecky (DFO Winnipeg) - ELA overview

Diane Malley (DFO Winnipeg) - Whole lake experimental addition of cadmium

Dave Schindler (University of Alberta) - Applications of ELA studies

Steve Eisenreich (University of Minnesota) - Concentrations, fluxes, and cycling of organic contaminants in the Great Lakes: air, water, sediment.

Chris Metcalfe (Trent University) - Toxicological effects of organic contaminants: A Great Lakes perspective.

Derek Muir (DFO Winnipeg) - Hypotheses, objectives and preliminary design of a whole-lake experiment with an organic contaminant

1345-1700 - Working groups meet at preassigned locations within CCIW

Tuesday, January 8th

0845 - 1100 - Discussion about the selection of PAHs versus PCBs

Working groups meet
Reports from Rapporteurs and final discussion

APPENDIX 2. Map of Experimental Lakes Area and Lake 375, progress to date and tentative plans

Progress to date and tentative plans for further studies are summarized briefly below. This is a revised version of the material presented by D. Muir at the workshop.

Progress to March 31, 1991:

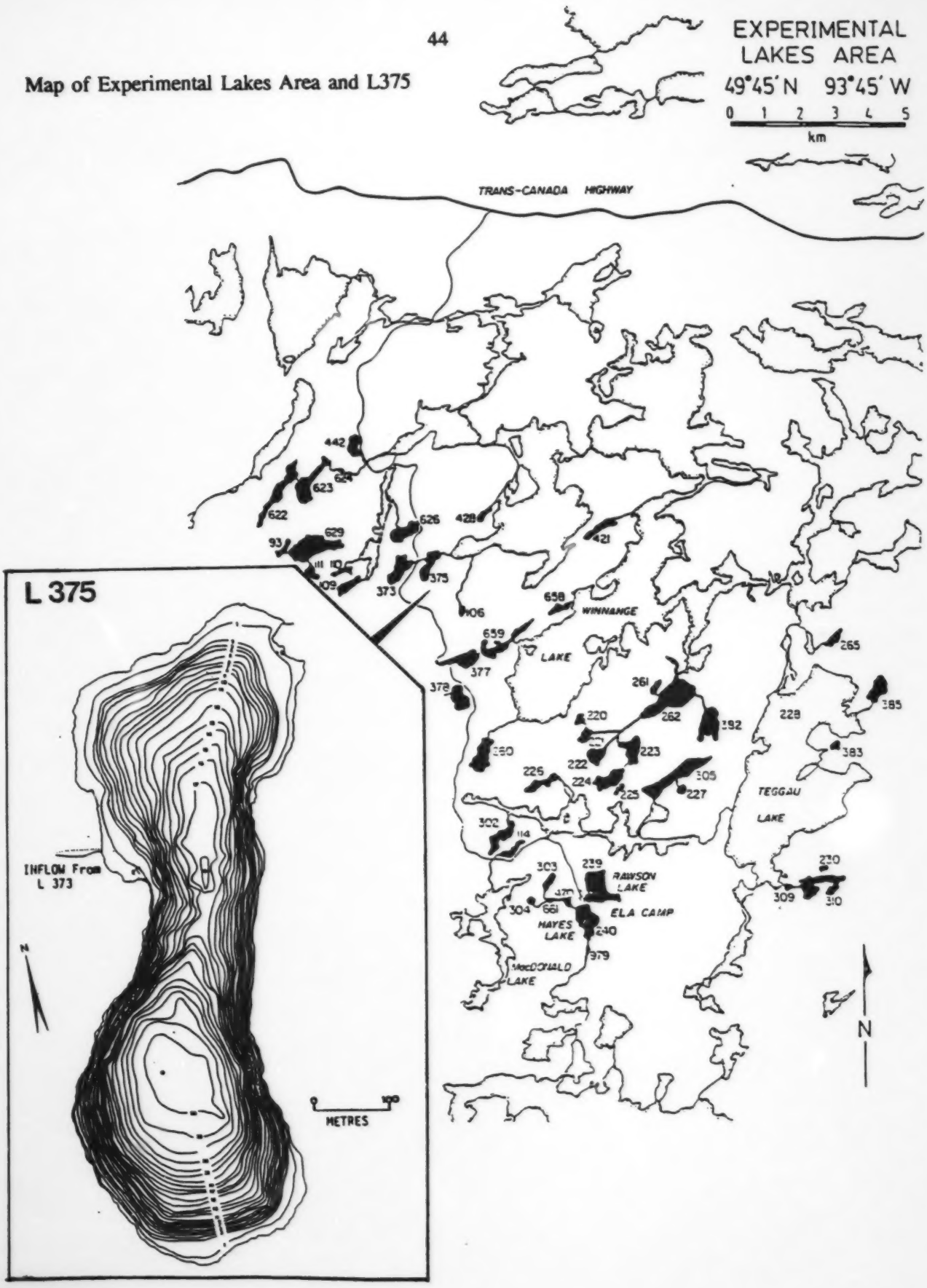
1989-90 - characterize fish populations in Lake 375
- determine background levels of contaminants in sediment and water

1990-91 - further characterization of fish populations
- characterize benthic community
- measure sedimentation rates
- characterize water chemistry, inflow/outflow
- background and seasonal cycles of MFO
- background contaminant levels in fish, benthos, sediments

Plans for 1991-92

- continue characterization of fish, zooplankton and benthic communities in L375
- further studies on sedimentation and particle flux in L375
- continue limnological characterization of L375 (water chemistry, inflow/outflow)
- continue background and seasonal cycles of biological indices (MFO induction, lipid peroxidation, histological parameters, steroid hormones) in fish from L375 and reference lakes
- continue background contaminant measurements in fish from L375 and Manomin Lake (immediately downstream).
- begin preliminary studies on remediation techniques for sediment-associated contaminants using nutrient additions to existing mesocosms in L375
- prepare documentation for conducting the necessary Environmental Impact Assessment screening of the experiment

Map of Experimental Lakes Area and L375



APPENDIX 3. Suggested questions to be addressed by working groups.

1. Environmental chemistry

- among the group of priority toxic chemicals, PCBs, dioxin/furan, PAHs, is there a consensus on the use of a particular chemical and why.
- what key matrices should be monitored to follow the fate of chemical? Can specific protocols be recommended?
- how should the organic toxicant be added - method, timing, duration of addition, and how will this affect the pathways and bioavailability of the chemical
- what is the predicted fate of the toxicant following addition in water, sediment and fish and lower food chain organisms
- what techniques will be developed that can be applied to the Great Lakes
- what data management considerations are forseen?
- are there important QA/QC aspects to be addressed?
- what can be done by DFO Winnipeg, what collaborations are necessary to make sure that essential studies get done?

2. Biochemical/physiological effects

- among the group of priority toxic chemicals, PCBs, dioxin/furan, PAHs, there a consensus on the use of a particular chemical and why.
- what biochemical, physiological and morphological responses must be measured. Can specific protocols be recommended?
- how do we relate cellular, tissue or organ level changes to population/ecosystem changes?
- given limited availability of some samples (of lake trout), identify approaches for field or lab effects studies.
- what techniques will be developed that can be applied to biochemical, physiological or morphological effects monitoring in the Great Lakes and near bleached kraft pulp mills.
- what data management considerations are forseen?
- what about health and safety aspects for the field site - re exposure to toxicants?
- what can be done by DFO Winnipeg, what collaborations are necessary to make sure that essential studies get done?

3. Population/ecosystem level effects

- is this an ecosystem experiment or a fish experiment?
- what taxonomic groups/species should be monitored for population level changes?
- do we need the same level of effort for all groups or what level of effort is sufficient for specific groups/species?
- at what life stages(s) do we anticipate changes? Is it possible to detect changes in population parameters (growth, survival, abundance) if they occur?
- are there potential "indicator" species we should target for more intense studies?
- what reference lakes should be used for biotic studies and is it necessary to maintain the same level of effort for reference (control) populations as for similar groups (species) in the manipulated lake?
- how do we relate changes in laboratory studies to population level changes?
- how do we relate cellular, tissue or organ level changes to population/ecosystem changes?
- what techniques will be developed that can be applied to the Great Lakes
- what can be done by DFO Winnipeg, what collaborations are necessary to make sure that essential studies get done?

4. Regulatory and Social issues

- is the experiment politically and socially feasible?
- what benefits and applications can reasonably be expected? What disbenefits and criticisms can be expected?
- are there important ethical, health and safety considerations and if so how should they be addressed?
- what are the practical requirements with respect to Environment Assessment and Review, DFO Habitat policy, the Fisheries Act? What steps must be taken to meet these requirements?
- how should participation in the experiment be governed?
- how should the experiment be managed?
- in terms of identifying a specific set of operational questions than can be answered unambiguously from defined data?
- in terms of defining variables to be measured and uncertainty to be tolerated?
- in terms of QA/QC?
- in terms of coordination and integration?
- in terms of provision of common services?
- in terms of project selection?
- in terms of interim and final reporting?
- how should the experiment be communicated to departmental senior management, other agencies and to the general public?

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